ABSTRACT

COMPARING FOOT PRESSURES DURING FEEDING IN TWO DISTINCT GROUPS OF CHILDREN

By: Abigail Brodrick Yakey

The purpose of this study was to observe typically developing children ages 6 to 18 months during feeding times and to study trends between foot pressures and awake arousal and attention levels. Ten subjects sat in a prototype highchair for three feeding trials and foot pressures were collected. Study results show that the older children exerted more foot pressure for a greater amount of time. Older children also used both feet more consistently when pushing. Future research is needed to determine the effects of foot pressure as a means of self-regulating and transitioning between awake arousal and attention levels.
COMPARING FOOT PRESSURES DURING FEEDING IN TWO DISTINCT GROUPS OF CHILDREN

A Thesis

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DEDICATION

This thesis is dedicated to my loving and encouraging parents, who have bestowed upon me constant love and endless support throughout my life.
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Developmental Guidelines of Feeding

During the first three years of life, extensive gains in coordination of swallowing and respiration, hand-eye coordination, sensorimotor integration, tone development, and appropriate psychosocial behavior development are acquired (Arvedson & Brodsky, 2002). At the time of birth, if the neonatal period and birthing process are non-traumatic, the infant will possess primitive reflexes that are optimal for feeding (Wolf & Glass, 1992). Oral reflexes develop as early as 12 to 14 weeks in utero and are in response generally to tactile stimuli. Initially the reflexes are programmed as responses to stimulation, but with maturity the reflexes can become integrated into functional purposes (Wolf & Glass, 1992). Reflexes, like rooting, suckling, sucking, and swallowing, are important for infants to meet nutritional needs during the first months of life when feeding from a bottle. Particular reflexes like the gag reflex, phasic bite reflex, transverse tongue response, and tongue protrusion are reflexes that are more directly related to chewing food rather than drinking liquids. In typical development, some reflexes persist throughout a lifetime, while others disappear with maturation (e.g. gag reflex and phasic bite) (Arvedson & Brodsky, 2002).

Feeding is a basic necessity of life and in the case of infants dependent upon social interaction for nutritional intake (Lipsitt, Crook, & Brook, 1985). Infant cues as expressed through behaviors should dictate feeding schedules and routines. In order for infants to become successful feeders typical behavioral transitions and patterns, and infant states of behavior must be carefully examined by caregivers. Thus, the evolution of feeding in children is a multifaceted process requiring achievement of developmental guidelines within a strict timeframe via an effective feeding relationship between parent and child. Although multiple theories of stages of development exist, most models overlap on important elements of each stage. The following basic skills should be met during the first 36 months of life and will be subsequently discussed.
## Table 1

*Stages of Development*

<table>
<thead>
<tr>
<th>Stage</th>
<th>Characteristics</th>
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<tr>
<td>Homeostasis (Stage 1)</td>
<td>• Self-regulation of visceral elements through the use of self-regulation techniques</td>
</tr>
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<td></td>
<td>• Transition into consistent infant patterns of behavior</td>
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<tr>
<td></td>
<td>• Maturation of sucking patterns</td>
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<td></td>
<td>• Increase in fine and gross motor abilities</td>
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<td>Attachment (Stage 2)</td>
<td>• Maturation of feeding skills</td>
</tr>
<tr>
<td></td>
<td>• Increase in control of environment</td>
</tr>
<tr>
<td></td>
<td>• Transition from dependent to independent feeder</td>
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During the first 3 months of life, infant behaviors are typically a result of reacting to needs of internal systems in an innate attempt to achieve homeostasis (Arvedson & Brodsky, 2002; Porges, 1996; Satter, 1990). Homeostasis is an active and emergent developmental milestone that allows for regulation and optimal performance of organ functions (Porges, 1996). Certain visceral elements like heart rate, blood pressure and body temperature, are controlled by self-regulatory abilities responding to feedback within and outside the body (Porges, 1996). Self-regulating behaviors may include the following: hands to mouth and face, bracing feet and legs, hand clasping, feet clasping, tucking (curled/rounded back), sucking, grasping and holding on, and looking (Ross, 2007; VandenBerg, Browne, Perez, & Newstetter, 2003). Previous research has found that children seek input through their feet to help reduce an overloaded sensory
experience and to self-regulate and calm themselves (Ross, 2007; VandenBerg, et al., 2003). These behaviors develop while in utero and are observable in the young infant as the nervous system develops and as the infant learns to have more control his behaviors. The purpose of the bracing behaviors is to seek contact with outside boundaries to inhibit movement and gain sensory input from the feet to achieve a calm state of behavior (VandenBerg, et al., 2003). Because infants this young are inconsistent with self-calming abilities and arousal levels (i.e. may be frequently drowsy or sleepy), the caregivers are responsible for providing the infant the necessary support to promote periods of quiet but alert states of behavior (Satter, 1990). Examples of support a caregiver can provide include swaddling the infant and adjusting posture (Ross, 2007). By supporting infants and tuning into cues, caregivers assist infants in learning patterns of behavior. As a result, the infant will achieve homeostasis and lead to greater interaction with the environment (Arvedson & Brodsky, 2002; Satter, 1990).

Once the infant becomes successful with homeostasis, the infant begins to transition to a stage of lesser reflexive feeding and more exerted volitional feeding. Frequently this transition occurs with the introduction of solid foods between 4 and 6 months. A decreased interest in sucking from a bottle or breast often begins as the infant increases visual interests in environment. Further as voluntary motor skills emerge, spoon feeding and cup drinking emerge (Arvedson & Brodsky, 2002; Lipsitt, et al., 1985). Interestingly, these developmental changes also correspond with the maturation of the advanced stage of sucking. Although the literature presents varied time lines, more mature sucking patterns develop between 6-9 months (Arvedson & Brodsky, 2002; Hall, 2001). The infant no longer suckles milk, but rather develops a tight lip seal, decreases mandible excursion and exhibits an up and down tongue movement (Hall, 2001). The maturation in sucking creates only a brief period of time required for an infant to drain a bottle or breast.

In creating independence during feeding, the infant begins to use fine and gross motor skills to explore the environment and to communicate with the caregiver. Simultaneous to feeding maturation milestones, the infant learns to develop a positive relationship with the caregiver and to engage in purposeful communication during mealtimes, thus creating attachment. At this time, an infant’s sensorimotor development
is sophisticated enough for the infant to have intentional movements to communicate a message (Satter, 1990). The parent continues to be an active participant in feeding by responding to the infant’s cues and keeping his attention on feeding, but also being cognizant not to overwhelm the infant with excessive stimulation during meals (Satter, 1990). Another important behavioral development during the attachment phase is the skill emergence of bringing toys to the mouth. Between 3 and 9 months, infants use their tongue and mouth to explore various textures of toys and consequently gradually decrease the trigger point of gagging (Carruth & Skinner, 1992). Other fine and gross motor developments such as finger dexterity and sitting contribute to the infant’s continuation towards independent feeding (Carruth & Skinner, 2002).

Once the attachment phase is completed, the child moves into the next developmental level of separation and individualization. Separation and individualization emerges around 6 months of age and continues up to 36 months of age. Feeding skills that develop early in this stage include spoon feeding, self-feeding, accepting thicker textured foods, independent management of a bottle and emergent biting and chewing skills (Arvedson & Brodsky, 2002; Carruth & Skinner, 2002). Another important feature of this stage is the child increasingly able to control over the environment and individuals. The infant is learning to recognize various emotional states and sensations of his body and this new awareness leads to a struggle of autonomy. The recognition of emotional states may directly be attributed to the maturation of the somatophysiological system, or the ability to process and understand sensory information. The role of the parent during feeding is modified to provide opportunities for the child to make choices within a structured environment (i.e. offering choices of foods and/or drinks and allowing the child to chose). Also, parents must balance independence of the child with self-control by introducing food rules during meals (Arvedson & Brodsky, 2002). As the child continues to traverse the individuation stage, an increase in testing boundaries is observed. As a result of infants and parents who successfully transition through homeostasis, attachment and separation/individualism, children have a positive mealtime attitude and should accept a variety of foods (Satter, 1990). Furthermore, as the child shifts from complete dependence of a caregiver, to being exclusively independent, feeding continues to be a social event (Arvedson, 1997; Arvedson & Brodsky, 2002).
Swallowing is comprised of four characteristic phases: oral preparatory phase, oral transit phase, pharyngeal phase and esophageal phase (Arvedson & Brodsky, 2002; Carrau & Murry, 1999; Hall, 2001; Perlman & Schulze-Delrieu, 1997). The oral preparatory phase is necessary for biting and chewing of food. Beginning between 9-10 months of age, the oral preparatory phase is volitional and only used with mastication of semi-solid and solid food (Arvedson & Brodsky, 2002). The length of the oral preparatory phase is dependent upon the texture and solidity of the food. When food enters the mouth, the lips close, sealing off the oral cavity. The tongue assists in lateralization of food over the molar surface to chew, grind and tear the food, while the buccinator muscles hold the food on the molars. As needed, the tongue sweeps the lateral sulci to clear out lingering food particles. Salivary glands secrete saliva to moisten, lubricate the food and begin the digestive process through the use of powerful enzyme used in breaking down food called ptyalin. Once sufficiently masticated, the bolus, or ball of food, is held in the median groove of the tongue. Throughout this phase, the velum is lowered and the tongue is raised to prevent premature entry into the pharynx and the airway remains open so nasal breathing can continue.

The oral transit phase of swallowing commences with the anterior-posterior movement of the bolus. Developing in utero, this phase consists of suckling, sucking and cup drinking in accordance with the development of volitional control emerging around 6 months of age (Scarborough, 2006). The tip of the tongue elevates to the hard palate and sequentially contracts along the hard and soft palate posterior to propel the bolus into the pharynx. As the bolus moves posteriorly, the velum elevates to prevent nasopharyngeal reflux. This phase lasts less than one second in typical and healthy adult individuals (Arvedson & Brodsky, 2002; Carrau & Murry, 1999).

Two distinct mechanisms must occur during the pharyngeal phase; 1) directing the bolus into the esophagus, 2) airway protection. Initiation of swallowing is varied by age of individual, region of oral cavity and stimulus type. Some oral regions appear to be highly sensitive to specific stimuli, whereas others contain broad areas with many different receptive fields (Wolf & Glass, 1992). This phase changes dramatically from infancy to adulthood and again with aging. Young children tend to initiate a swallow at
the level of the valleculae whereas adults typically trigger a swallow at the anterior faucial pillars (Arvedson & Brodsky, 2002). Once initiated, the swallow triggers a series of events. All simultaneous, the soft palate elevates, the tongue is elevated and the tongue base propels the bolus posterior, the pharyngeal constrictors contract to squeeze the bolus through the pharynx and the larynx elevates and closes to protect the airway. As the swallow is ongoing, the larynx employs several mechanisms to protect the airway. The larynx elevates and moves anterior, causing the epiglottis to close over the larynx, the false and true vocal folds adduct to cover the airway, thus causing respiration to cease. The upper esophageal sphincter (UES)/cricopharyngeal sphincter relaxes and opens, allowing the bolus to enter the esophagus and ending the pharyngeal phase. Again, this phase of swallowing typically lasts about one second (Carrau & Murry, 1999).

The final stage of swallowing is the esophageal stage where the bolus transfers to the stomach. The striated, voluntary muscles of UES at the rostral end relax, opening the esophagus and allowing contraction of the longitudinal and circular muscles. Peristaltic contraction, secondary to changes in esophageal pressure, propels the bolus downward until reaching the smooth, involuntary muscles of the lower esophageal sphincter (LES) at the caudal end. The bolus empties into the stomach after the relaxation of the LES (Perlman, et al., 1997; Wolf & Glass, 1992).

Fundamental Organization of the Human Nervous System

The human nervous system is responsible for transmitting information to and from the brain with the use of approximately 100 billion neurons, or basic cellular units (Vander, Sherman & Luciano, 2001; Zigmond, Bloom, Landis, Roberts & Squire, 1999). Neurons are the fundamental cells that comprise the human brain and spinal cord. Classification of neuronal purpose is divided into efferent (motor), afferent (sensory) or interneuron (connections). Efferent neurons carry motor messages from the brain out to various locations in the body, whereas afferent neurons carry sensory information from outside and within the body to the brain. Approximately 100 trillion interneurons serve as connections within the nervous system itself (Vander et al., 2001; Zigmond et al., 1999). The anatomy of a neuron includes a soma, or cell body, dendrite(s), axon and axon terminals. The nucleus of the neuron is enclosed within the soma and the axon acts
as an extension of output of the soma. Dendrites are important structures because they serve as addition synapse, or meeting, points with other neurons extending from the soma. At the end of the axon are axon terminals, which serve as housing agents for various neurotransmitters (Vander et al., 2001; Zigmond et al., 1999). Together, neurons form tracts that carry and relay messages throughout the human body via the central and peripheral nervous systems.

Anatomy of the Central and Peripheral Nervous Systems

The human nervous system is divided into different areas that serve various functions. The following outline provides the structure and functions of each area. The human nervous system is divided into the Central Nervous System (CNS) and the Peripheral Nervous System (PNS). Please refer to Appendix A for an overview of the CNS and PNS.

Sensory Systems

Sensory systems exist to tell the CNS what is occurring in the internal and external environment. This paper will only address sensory systems and the external environment. Specifically, the tactile sensory systems process information regarding temperature, pressure, touch, pain, and stretching of muscles. Sensory systems consist of sensory receptors, both internal and external, that are responsible for receiving stimulation and neural pathways that travel to the brain (Vander et al., 2001; Zigmond et al., 1999). Some sensory information can be processed and cognition of the sensory information occurs, whereas other information is processed but never reaches consciousness. For humans, a “sensation” is when an event is acknowledged but “perception” is when the sensation is understood and interpreted. The process of feeling and perceiving a sensation is complex and requires many neurological structures to be intact (Vander et al., 2001; Zigmond et al., 1999).

Somatosensory System

Specific sensory systems exist to process different types of information. Three broad categories can be defined to include all essential functions:
- Exteroceptive functions: Sensations of touch, temperature and pain
- Proprioceptive functions: Kinesthetic sensations of positions and movement
- Interoceptive functions: sensory information from internal organs (Zigmond et al., 1999).

Somatic sensation consists of information received from the skin, muscles, bones, joints, and tendons. Three specific sensory receptors exist within the exteroceptive category to receive various sensations. First, mechanoreceptors vary in their location within the skin and are responsible for transmitting sensations of touch/pressure, vibrations and superficial touch. Mechanoreceptors are generally sub-classified by a receptor type:

- Meissner’s (tactile) corpuscle – light touch, flutter, motion
- Merkle’s (tactile) corpuscle – touch, texture, pressure
- Pacinian (lamellated) corpuscle – deep pressure, vibration
- Ruffini corpuscle – warmth, possibly skin stretching

Posture and movement, including the magnitude and rate of stretch of muscles, correlate with muscle-spindle stretch receptors. Collaboration from vision, vestibular organs and mechanoreceptors is required for the senses of posture and movement due to their complex nature (Vander et al., 2001; Zigmond et al., 1999). Second, two types of thermoreceptors receive information about temperatures. Warmth receptors respond to temperatures 30-43 degrees Celsius. In contrast, cold temperatures are stimulated by small, incremented drops in temperature and trigger cold thermoreceptors. Finally, nociceptors receive types of pain like burning/sharp pain, mechanical deformation and excessive heat. All of these specialized sensory receptors are located throughout the body. Overlapping areas on the body where neuron activity secondary to stimulation occurs are called receptive fields, or dermatomes (See Figure 1) (Felten & Jôzefowicz, 2003; Vander et al., 2001).
Even within the oral and pharyngeal cavities and the larynx, abundant sensory receptors detect taste, touch, pressure, pain, location and temperature to help modulate various muscles of mastication and swallowing (Arvedson & Brodsky, 2002; Carrau & Murry, 1999). Chemoreceptors, stretch/pressure receptors (baroreceptors) and temperature receptors are the underlying components of the sensory aspects of pharyngeal swallowing (Wolf & Glass, 1992).

Proprioceptive, or kinesthetic, sensations come from the ability to sense joint positions, direction and velocity of joint movements, and the amount of effort needed to lift objects (Zigmond et al., 1999). Thus said, kinesthetic sensations are associated with the motor system. Without specific proprioceptive sensations, limbs and body parts would wrongly interpret and interact with the external environment. Interoceptive sensations often alert the brain to internal changes without conscious thinking; thus, these sensations often fall under the responsibility of the autonomic nervous system (Zigmond et al., 1999).

**Sensory Units and Receptors**

A sensory unit is one afferent neuron with many receptor endings. The basic component of sensory unit is the sensory receptor. Sensory receptors exist to detect and process information from the outside world and from the body’s internal environment.
Sensory receptors are located at the peripheral ends of afferent neurons. Receptors can either be specialized membranes at the end of afferent neurons or separate cells that affect afferent neurons. Each sensory receptor responds best to one specific form of stimulus energy, called an adequate stimulus (Vander et al., 2001). The sensory receptor receives the energy from the stimulus thus changing the energy into a graded potential, which exists solely to trigger action potentials. Action potentials are all-or-nothing electrical signals that may be maintained to allow for travel of long distances (Felten & Jõzefowicz, 2003; Vander et al., 2001). Following the trigger in initiation, the action potential then travels up to the CNS until the final destination within the cerebral cortex is reached.

The process of changing the stimulus energy to graded potentials and action potentials is called stimulus transduction. The transduction process works by the opening and closing of ion channels throughout the afferent neurons. The type of transduction depends on 1) whether the sensory receptor is located on the peripheral end of an afferent neuron or 2) on a separate cell. In the first scenario, as the stimulus energy is received, the sensory receptor’s membrane allows for a change in ion flux as the energy travels across the membrane. This process of changing the energy into graded potential is called receptor potential (Vander et al., 2001). The current runs along the axon of the afferent neuron until it reaches the first node of Ranvier of a myelin sheath. Here the graded potential is changed into action potential. This process occurs only if the node of Ranvier is depolarized and the difference in ion levels sparks the change into action potential. In the second scenario in which the sensory receptors are located on a separate cell, the process of reaching action potential is identical except for one additional step. The sensory receptor’s membrane still converts the energy into receptor potential, but in order for this to reach the afferent neuron the receptor potential must trigger the release of a neurotransmitter. The neurotransmitter travels to the afferent neuron, creating a synapse. The neurotransmitter binds with specific sites of the afferent neuron and creates a graded potential. This graded potential determines action potential frequency but not the magnitude since action potential is an all-or-nothing process. However, the magnitude of receptor strength is dependent on the strength of the stimulus, the rate of change of the stimulus strength, the temporal summation of successive receptor potentials (build up of sequential postsynaptic potentials), and a concept called adaptation (Felten & Jõzefowicz,
Adaptation creates a decrease in frequency of action potential despite a steady level of strength of stimulus due to a decrease in sensory receptor sensitivity.

**Central Somatosensory Pathways**

Sensations travel along a bundle of ascending, parallel, three-neuron chain of nerves to reach the cortex. Within the spinal cord are two afferent, contralateral nerve tracts that process sensations. The first processes the modalities of deep pressure, light touch, vibration and proprioception for the body. While these modalities typically follow this path, for some people light touch may be processed through the second tract. Beginning in sensory receptors and traveling through the dorsal columns of the spinal cord, somatosensory inputs are carried to the dorsal column nuclei of the lower medulla. Here, new axons from the dorsal column nuclei cross the midline and form a fiber bundle called the medial lemniscus. Subsequently, this tract is called the dorsal column/medial lemniscus tract. Finally, the axons terminate in the dorsal thalamus, specifically the lateral division of the ventro-posterior nucleus, allowing axons to reach the first somatosensory cortex at the postcentral gyrus (Zigmond et al., 1999). The dorsal column/medial lemniscus tract will always override the anterolateral/spinothalamic tract when both tracts are simultaneously processing sensory information.

The anterolateral/spinothalamic tract processes information from pain, temperature sensory receptors and for some people, light touch (Felten & Jôzefowicz, 2003; Vander et al., 2001; Zigmond et al., 1999). Sensory information travels through the spinal cord like the dorsal column/medial lemnisus tract, but the first order neurons end in the spinal cord itself. The axons of the spinal neurons then cross midline of the spinal cord and ascend through the anterolateral quadrant of the spinal cord to either the brainstem or nuclei of the dorsal thalamus (Zigmond et al., 1999). The final destination for both pathways is at the brain stem’s reticular formation.

**Reticular Formation**

Within the brainstem a large area called the reticular formation exists. Although extensive research has been conducted regarding the reticular formation, questions still remain about the exact location and boundaries of this area. Because all nerve fibers that travel through the spinal cord, cerebrum and cerebellum must pass through the brainstem,
the reticular formation is an area of neuron cell bodies mixed with bundles of axons and is essential for life (Vander et al., 2001; Zigmond et al., 1999). All regions of the central nervous system send information that is integrated in the reticular formation leading to involvement with several motor functions, control of respiratory and cardiovascular function, attention and regulation of sleep and wake cycles. Clusters of neurons in the reticular formation controlling specific functions like swallowing, respiration, orientation of the body in space, and vomiting are positioned side-by-side with neurons responsible for various other functions. Through selectively activating neurons in the brain and inhibiting others, wakefulness and attention are controlled by ascending fibers from neurons within the reticular formation. Also involved with descending fibers, the reticular formation influences efferent and afferent pathways involved with motor movement (Vander et al., 2001; Zigmond et al., 1999).

Sensory-Processing Development and Disturbances

Typical children with intact sensory perception and registration within the central nervous system will acknowledge tactile input and demonstrate some level of tolerance. For the purpose of this thesis, only the system of touch, specifically deep pressure, will be addressed. The sense of touch, whether oral or whole body, has the greatest impact on feeding and if the perception or registration of touch sensory input is abnormal, feeding problems are likely to occur (Glass & Wolf, 1992; Wolf & Glass, 1998). Tactile input can refer to whole body touch, general handling, and/or oral touch associated with feeding. While some children may develop degrees of oral tactile defensive behaviors with new textures, these behaviors are developmentally expected within a continuum of behaviors. However, over time, oral tactile defensive behaviors typically deteriorate as the child learns to accept the new stimulation (Carruth & Skinner, 1992; Comrie & Helm, 1997; Wolf & Glass, 1992). Normal infant development displays simple behavioral organization by integrating reflexes and adapting behaviors to keep a calm and alert state. As the infant learns to adapt to stimulation, these skills will assist to prevent physiological disturbances caused by increased sensory input (Carruth & Skinner, 1992; Kopp, 1982).

A child with sensory-processing disturbances may have generalized irritability and if the child has the ability to self-calm and self-regulate, these behaviors should be
noted. Commonly demonstrated dysfunctional behavioral, emotional, and attention-based responses represent a continuum ranging from: absent response, hyporeactive response, hyperreactive response, and sensory-defensive response to oral sensory input (Arvedson & Brodsky, 2002; Glass & Wolf, 1998; Hanft, Miller, & Lane, 2000; Wolf & Glass, 1992). While these responses are limited mostly to the oral cavity, recent research notes that children with chronic feeding problems display an abnormal touch response pattern (Scarborough, Boyce, McCain, Oppenheimer, August & Strinjas, 2006). If a child perceives oral sensory input during feeding as overwhelming, he may demonstrate avoidance behaviors related to eating and feeding and become irritable at mealtimes. A child may also enlist calming and coping strategies to attempt to organize his environment during times of sensory overload and such behaviors should be noted (Arvedson & Brodsky, 2002).

An absent response to firm, tactile pressure is indicative of a severe sensory impairment. When absent or even significantly diminished responses are present, often neurological compromise of integrity is suspected (Wolf & Glass, 1992). Children with hyporeactive responses tend to seek extra oral stimulation because of reduced taste, temperature and proprioceptive input of food to elicit a response (Arvedson & Brodsky, 2002; Wolf & Glass, 1992). Interestingly enough, even typical children experience phases of mouthing objects in their environments. Mouthing behaviors commonly begin after 1 month of age and peak around 6 months, with a sharp decrease of mouthing around 24 months old (Fessler & Abrams, 2004). Often, the sensory seeking behaviors may be engaging and not necessarily direct oral stimulation. Drooling may also accompany poor chewing and sucking skills, indicating poor bolus control or the need for continual stimulation for salivary glands. Poor or low muscle tone may be the cause of hyporeactive responses.

Hyperreactive responses are those that are exaggerated compared to the amount of stimulation present. When hyperreactive responses are observed with oral stimulation, the child typically presents with a CNS disorder, respiratory difficulties, esophagitis and/or gastroesophageal reflux disease (GERD) and the primary etiology must be addressed first before implementing therapy techniques. Children with hyperactive responses may gag and demonstrate behavioral state changes when tactile stimulation is
presented to the oral cavity or surrounding regions (Scarborough et al., 2006). Hyperreactive responses also present as “fight or flight” behaviors (Hanft et al., 2000). Children with oral sensory aversion often avoid stimulation because of previous unpleasant oral-tactile experiences and/or neurological reasons. When a child avoids sensory input in the mouth, the behaviors seen may be not allowing anything in the mouth, limiting by textures and tastes, or not allowing stimulation by something other than the child’s own fingers.

**Pediatric Feeding Difficulties**

Feeding problems are not labeled until a child’s feeding behaviors do not meet expected performances. One major indicator of feeding difficulties is an inability to gain weight (Arvedson & Brodsky, 2002). When gathering a feeding history, specific symptoms may lead to suspected feeding difficulties. Difficulties with transitioning through mealtimes, poor rhythm sucking and frequent agitation are all signs that an assessment of state behaviors is needed. Impairments in physiologic measures may include color changes, apneic spells and brady/tachy-cardia. However, other parameters such as excessive gagging or problems transitioning to a new mode of feeding may also indicate irregular tactile sensory responses. In these cases, the underlying etiology may be impaired physiological stability (Scarborough, 2002). Although feeding problems in children appear to be common, there continues to be inconsistent diagnostic criteria to define feeding problems. With that said feeding difficulties are estimated to occur in 2 to 45 percent of the general pediatric population (Arvedson & Brodsky, 2002). Even more prevalent, children with developmental delays show 33 percent present with feeding disturbances (Arvedson & Brodsky, 2002). Mild feeding problems, mostly including behavioral aspects, have greater prevalence (25 to 40 percent) in the typical toddler and school-age populations, but often are transitory in nature as part of the struggle for autonomy (Arvedson & Brodsky, 2002).

**Etiologies of Feeding Disorders**

Children who present with feeding disorders are a diverse population with numerous etiologies. The potential causes of dysphagia, or impairment in swallowing, are vast and often vague in the pediatric population due to a decreased amount of research compared to adult populations (Hall, 2001). A common classification for
feeding disorders is the organic vs. non-organic origin (Scarborough, 2002). Organic etiologies are those present at birth but if a child has a feeding disorder, and all organic reasons have been ruled out, then behavioral, or non-organic, etiologies must be considered. Although non-organic feeding problems are primarily behavioral, some secondary physiological aspect should be appreciated (Arvedson & Brodsky, 2002; Wolf & Glass, 1992). Due to some feeding disorders accounting for both organic and non-organic etiologies, the term “mixed” was created. With limited definitions of the term “mixed” and what it encompassed, research and literature tend to use other classification systems (Scarborough, 2002).

Another classification system identified seven major etiological categories: anatomic, neurologic, gastrointestinal, cardiorespiratory, metabolic, psychosocial, and other (Scarborough, 2006). Sensory-processing deficits may co-occur with any etiology and require specialized treatment approaches. The impact on feeding is dependent upon the etiology and its severity. Research focuses on sensory-based feeding problems as a result of immaturity, chronic illness, abnormal oral-tactile stimuli responses, delayed introduction to oral feeding, and neurological impairment (Glass & Wolf, 1998). More current research focuses on infants and toddlers who present with abnormally significant gagging or behavioral state changes resulting from oral and body tactile pressure (Scarborough et al., 2006). Gagging and state changes are commonly observed however rarely documented and researched until recently when proposed that when a child is deprived of normal oral sensory input during the first year of life, the nucleus tractus solitarius, which is responsible for coordinating autonomic development, may be directly affected and influence the gag reflex and behavioral state regulation patterns (Scarborough et al., 2006). Although the view of this paper agrees with a physiologically based etiology for sensory-based feeding difficulties, all other areas of assessment should be included during a feeding evaluation.

Anatomic evaluation should include careful examination of structural deviations potentially involved with feeding. Specifically, the mandible, maxilla, palate, hyoid, ribs and cervical vertebrae should be observed directly or indirectly during an evaluation. Also to be evaluated in the anatomic category is the cartilages of the larynx, nasal cavity, trachea and bronchi. A final important area needing evaluation is the muscles involved
Neurological processing capabilities have a large impact on feeding abilities. Common neurological diagnoses that affect feeding are listed in Table 2.

Table 2

<table>
<thead>
<tr>
<th>Common Neurological Diagnoses</th>
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<tbody>
<tr>
<td>Cerebral Vascular Accidents (CVA’s)</td>
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<tr>
<td>Anoxia/Hypoxia</td>
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<tr>
<td>IVH (grades I-IV)</td>
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<tr>
<td>Tumors</td>
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<tr>
<td>Congenital or Acquired Infection</td>
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<tr>
<td>Drug exposure</td>
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<tr>
<td>Traumatic brain injuries</td>
</tr>
<tr>
<td>Shaken baby syndrome</td>
</tr>
<tr>
<td>Illness (meningitis)</td>
</tr>
<tr>
<td>Various Syndromes</td>
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<tr>
<td>Hydrocephalus</td>
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Gastrointestinal etiologies affecting feeding commonly include gastrointestinal tract disorders (e.g. constipation) and GERD (Hall, 2001; Scarborough, 2002; Wolf & Glass, 1992). GERD can be treated with medication, a surgery called fundoplication, or a combination of both. Other gastrointestinal areas to examine are food allergies, nutrition related ailments and failure-to-thrive (Scarborough, 2002).

When assessing the cardiorespiratory system, both cardiovascular and respiratory systems need to be evaluated separately and how the functions affect the system as a whole. The cardiovascular system must be anatomically intact to allow proper oxygenation throughout the body. Without proper oxygen, a child with feeding difficulties will easily tire (Scarborough, 2002). In turn, the respiratory system must be fully developed and functioning properly to protect the airway. Examples of diagnoses with mastication and respiration (Scarborough, 2002). Common anatomic etiologies include cleft lip and palate, vascular rings, micrognathia, and myopathies resulting from syndromes (Hall, 2001; Wolf & Glass, 1992)
that will negatively affect feeding include bronchopulmonary dysplasia (BPD), clefts or fistulas of the larynx, esophagus or trachea, esophageal atresia, and tracheal and/or brochomalacia (Scarborough, 2002). Another area that may need to be considered is children with tracheostomies. While using a tracheostomy tube, laryngeal function can be decreased and the respiratory system may be compromised.

Etiologies stemming from metabolic disorders include problems with renal, endocrine, blood, and lymph systems. Often these areas require very individualized plans of care, specifically regarding rare syndromes and associated problems (Scarborough, 2002).

Psychosocial etiologies are those that arise from behavioral problems. These behaviors may be related to abuse, emotionally based problems, poor caregiver models during feeding times, learned aversions, and reinforcement patterns (Scarborough, 2002). Interestingly, behavior problems frequently develop secondary to sensory-processing deficits. One aspect that is critical to the success of feeding is cooperative behavior. Negative behavior during feeding can correlate to reduced success of feeding, which may result in numerous detrimental effects. Common effects include reduced weight for age, inefficiency in gaining weight, deterioration of health, and negative social issues (Arvedson & Brodsky, 2002). Behavioral feeding disorders can develop throughout the duration of any of the three major developmental stages of feeding, though most occur during the attachment stage or the separation/individualization stage (Arvedson, 1997; Arvedson & Brodsky, 2002). Common behavioral patterns observed are food refusal, picky eating, poor appetite, and consequently, lack of weight gain. Crying, non-engaging behaviors, decreased vocalizations, frequent vomiting/spitting up, and defiant behaviors should be noted to have a link to physiological etiologies and not viewed as solely a behavioral response. While these behaviors are shown by the infant, the caregiver may also display negative behaviors that may initiate or reinforce the feeding disorder and lead to a breakdown in the child/caregiver dyad (Arvedson, 1997). In order to have successful feeding, the caregiver is responsible for structuring mealtimes by establishing regular mealtimes, keeping mealtimes limited to 30 minutes, feeding in a neutral environment, never playing games, and following procedural scripts during the mealtime (Arvedson, 1997; Satter, 1990).
Finally, other factors that may cause feeding difficulties can include pain, detrimental effects of medication, various cognitive levels, and nutrition. Other etiologies may include genetic, secondary to systemic illness and/or resolved medical condition, and psychosocial (Arvedson, 1997; Arvedson & Brodsky, 2002; Scarborough, 2002). Working within an organizational structure where feeding disorders may be influenced by multiple etiologies allows speech pathologists to gather more information and be more specific in diagnosing feeding disorders.

*Sensory-based Feeding Etiologies as Specified by Physiological Stress Indicators*

While the above categories account for many of the clinical cases seen with feeding disorders, sensory-processing based etiologies that impact feeding are a common occurrence in the pediatric population (Wolf & Glass, 1992). Feeding is greatly influenced by the integrity of a number of sensory systems – touch/pressure, movement/vestibular, auditory, visual, olfaction and taste. This paper will only focus on touch/pressure systems and the physiologic parameters that may lend evidence to sensory-based problems.

If a child must endure invasive oral procedures and medical treatment, physiological responses may develop and cause a negative behavioral response. However, the physiological responses are the root of response and consequently, may carry over to all oral stimulation. When evaluating an infant feeding in a medical setting, the work and effort of feeding is evident with changes in physiological indicators like heart rate, respiratory rate, oxygen saturation levels, and autonomic and visceral indicators of stress. To fully evaluate an infant during feeding, sharp clinical observations and precise technological measurements should be used. Many of the technology resources are only available in hospitals and are used with children who present with feeding difficulties. Heart rate (HR) in infants can be best monitored using a cardiac-respiratory (CR) monitor, which provides an output of wave-form patterns and triggers an alarm if the change of heart rate is beyond a preset limit (Wolf & Glass, 1992). When utilizing a CR monitor during feeding, initial and final HR should be monitored as well as any changes, including highest and lowest values. Clinical observations should accompany the monitoring to relate any behaviors to changes in HR. Such behaviors can include cyanosis (blue tinting of face and lips), facial expression...
changes, retraction from food source, and any other adverse behaviors. Typical heart rates range from 120 to 140 beats per minute (BPM) in full-term infants. Determining an infant’s baseline HR will allow for better interpretation of bradycardia (drop in HR) or tachycardia (elevated HR). Bradycardia is classified with a drop in HR to below 90 or 100 BPM and can be a significant event when noted with feeding. Bradycardia is particularly related to vasovagal responses and pooling of food in the valleculae (Comrie & Helm, 1997). Tachycardia is defined as an above normal HR and indicates an increased level of exertion (Wolf & Glass, 1992). If during feeding, bradycardia or tachycardia is noted, feeding should be ceased and later modified to eliminate these threatening situations for infants.

Respiratory rate (RR) can also be monitored using a CR monitor and helps to establish breathing pattern wave-forms for an infant. Full-term infants have a typical range of 30 to 60 breaths per minute (BPM), however research has shown that infants have an elevated BPM (average of 58) while awake and a slower BPM (30-60) when sleeping (Wolf & Glass, 1992). A vital element of respiration to observe for is apneic events. Apnea is defined as a cessation of respiratory airflow for any length of duration (Wolf & Glass, 1992). Brief apneas of less than 15 seconds may be observed with any age, but when the episodes are greater than 20 seconds in length or are accompanied by cyanosis, abrupt onset of pallor (extreme paleness), hypotonia, or bradycardia then apneic episodes are considered pathologic (Wolf & Glass, 1992). Because respiration and swallowing must be coordinated for safe feeding, feeding should be restricted during times of abnormal respiratory rates.

Another technical method of evaluating feeding is using oxygen saturation levels. Oxygen saturation is the amount of oxygen present in the blood at a given time. To measure levels a pulse oximeter should be used to determine how much oxygen is present in capillary blood flow (Wolf & Glass, 1992). An oximeter reading is measured up to 100 percent and a level of 95 percent or above is normal for most infants. Any level below 90 percent is considered some level of hypoxia for typical children, although lower levels may be expected of atypical cases (i.e. cardiac babies) (Scarborough, 2006). During desaturation episodes, color changes in infants can accompany decreased levels of oxygen. When an infant’s skin around his mouth or eyes progresses from a pink blush to
a dusky/gray or blue color, this suggests a decline in oxygen saturation. If a sudden color change occurs, an acute event of apnea or dramatic drop in oxygen is occurring (Wolf & Glass, 1992).

**Autonomic Stress Indicators**

The regulation of the autonomic nervous system is critical in evaluating an infant with feeding difficulties. Autonomic stress indicators are similar in observation to state behaviors, however due to physiological causes, any noted changes should be indicative of feeding difficulties and should not be ignored. The cues during feeding suggest the infant is experiencing stress and feeding performances may be affected are listed in Table 3.

Table 3

<table>
<thead>
<tr>
<th>Autonomic Stress Indicators</th>
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<tbody>
<tr>
<td>Sighing</td>
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<tr>
<td>Yawning</td>
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<tr>
<td>Sweating (diaphoresis)</td>
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<tr>
<td>Hiccupping</td>
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<tr>
<td>Gasping</td>
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<tr>
<td>Straining</td>
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<tr>
<td>Coughing</td>
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<tr>
<td>Gagging/Choking</td>
</tr>
<tr>
<td>Spitting up (emesis)</td>
</tr>
<tr>
<td>Color change</td>
</tr>
<tr>
<td>Irregular respirations</td>
</tr>
</tbody>
</table>

(Ross, 2007; Wolf & Glass, 1992)

Changes in behavioral states during feeding must be interpreted as a communicative intent of the infant because he cannot verbalize his feelings. Behaviors like falling asleep, worried expressions, and inconsolable crying are atypical for feeding times and should be observed and monitored closely. Rapid changes in states represent a stress signal and the caregiver should modify the mode of sensory input. Other more
immediate concerns regarding autonomic regulation functioning include vasovagal responses, particularly bradycardia, gag reflex responses, and fluctuations in temperature control (Als, 1982; Scarborough, 2002; Scarborough, 2006). Discovering effective and individualized sensory input allows for attentive behavior, usage of self-calming strategies, and reduced complications during feeding (Arvedson & Brodsky, 2002).

Current Treatment Approaches

Professionals in speech-pathology aim to use an evidence-based practice approach to treat dysphagia and often practice the most current methodology. By use of this procedure, clinicians often participate in interdisciplinary collaboration to provide appropriate treatment for all patients (Arvedson & Brodsky, 2002). However, a lack of research focusing on sensory-processing disorders and feeding due to physiological impairment is evident. Current research and treatment for behavioral feeding difficulties focuses on using behavioral modification strategies, targeting skill deficit problems, cognitive-behavioral therapy, and pharmacologic treatment approaches to decrease the amount and/or severity of feeding problems (Arvedson, 1997; Arvedson & Brodsky, 2002). The behavioral modification approach utilizes positive praise for appropriate feeding behaviors and ignoring inappropriate behaviors. Skill deficit problem recommendations are used for children that require assistance in learning necessary skills. Through the use of shaping, modeling, and prompting, the child learns skills in isolation and later generalizes these skills to feeding routines. Cognitive-behavioral therapy often includes family therapy and focuses on changing negative and faulty beliefs about swallowing and feeding. The use of pharmacologic treatment is often combined with cognitive-behavioral therapy; however this approach is rarely used. Stimulating appetites through the use of medicine may be successful with certain populations (e.g. panic disorder), but a safe approach and protocol is not yet widely accepted (Arvedson & Brodsky, 2002). Although these approaches are supported with minimal research and data (Arvedson, 1997; Arvedson & Brodsky, 2002), the sensory environment of the child during feeding is not being addressed in any of these approaches. Another area not addressed is the physiological impairments causing the feeding difficulties. Depending on which approach is selected to be utilized during therapy, oral-motor treatment focuses on targeting coordination of swallowing, respiration and talking by way of sensory
integration to increase both communication and oral feeding. Behavioral management programs often co-exist with this treatment approach. Direct and indirect approaches to oral sensorimotor functioning includes oral stimulation, alterations in environment, changes in seating or positioning, introducing additional communication prompts, teaching calming techniques, and altering food characteristics (Arvedson & Brodsky, 2002).

Specific treatment programs for oral sensitivity and aversion require adaptation of environmental factors, modification of specific foods and/or utensils, and direct techniques. Using a hierarchy of desensitization teaches a child with sensory-processing deficits how to manipulate his feeding environment appropriately, learn meal time scripts, and be active in a stable environment (Arvedson & Brodsky, 2002). Managing oral sensory defensiveness and aversion requires a trusting relationship between the clinician and child. A whole-body approach to input is recommended because the avoidance behaviors are so great, limited access to the oral cavity is common (Arvedson & Brodsky, 2002). Children with hyporeactive responses benefit from treatment approaches that aim to exaggerate sensory input and stimulate diminished responses. Treatment techniques for children with hyperreactive responses to oral-tactile stimulation often include reducing aversive stimuli, allowing oral exploration, integration of oral stimulation into daily lives, and application of deep touch/pressure (Wolf & Glass, 1992). Also to note, promoting stability for both hypo- and hyperreactive children through the adjustment of positioning is typically required (Arvedson & Brodsky, 2002). Through appropriate use of a highchair, this factor may be eliminated for some children, however, additional variables relating to the type, size and structure of the highchair still need to be researched.

Attention and Arousal Levels of Infants

When interacting with an infant, one of the most important, if not the most important, observations is the infant’s state of arousal. Infants learn to have the ability to manage or ignore stimulation and to adapt their behavior towards environmental stimuli as they mature (Brazelton, 1973; Wolf & Glass, 1992). Environmental stimuli can include sights, sounds, and smells from external surroundings, internal signals from the infant's body, and movements (i.e. rocking) directly applied to the infant (Wolf & Glass,
When receiving stimulation of any kind, the physical and emotional reaction demonstrated is directly correlated to the alertness or arousal level of the infant. The behaviors thus exhibited by the infant communicate levels of stress, self-regulatory behaviors, and social interactions (Wolf & Glass, 1992). All decisions regarding amount and mode of stimulation should be made with the intention of keeping the infant in a quiet, alert stage of arousal.

**Brazelton Neonatal Behavioral Assessment Scale**

To help classify and identify attention and arousal stages, the Brazelton Neonatal Behavioral Assessment Scale (NBAS) was created in 1973 with six states of arousal, which was updated in 1984 to include a seventh stage. The purpose of the NBAS is to observe infants’ behavioral responses when demands are placed upon their physiological systems. The NBAS includes stages that are a continuum aimed at evaluating the infant’s autonomic nervous system and the interactive behavioral responses to incoming stimuli (Brazelton, 1973). The stages are as follows:

- **Stage One:** Deep Sleep
- **Stage Two:** Light Sleep
- **Stage Three:** Dozing/Drowsy
- **Stage Four:** Quiet Alert
- **Stage Five:** Active Alert
- **Stage Six:** Alert Agitated
- **Stage Seven:** Crying

(Brazelton, 1973; Brazelton, 1984)

Stages one and two are sleep states, indicating low activity level. Stage one is indicative of a deep sleep with no spontaneous movement and delayed response of deep external stimuli. Infants in this stage have regular respiratory patterns and no rapid eye movements (REMs). Stage two is a light sleep with apparent REMs and responsiveness to internal and external stimuli, often resulting in a change of state. Other movements seen in stage two are random limb movements and sucking behaviors.

Stages three, four, and five are awake states with arousal varying from drowsy to alert. Infants in stage three may be semi-dozing and their eyes flutter open and closed. The infant frequently shifts position and responds to stimulation easily. Quiet alertness is
characteristic of an infant in stage four. The infant is awake and focused on a visual or auditory stimulus. Minimal movements are noted in stage four as well as slow redirection to a new stimulus. The quiet alert stage is the most optimal stage for learning new information (Brazelton, 1973; Brazelton, 1984; Wolf & Glass, 1992). Stage five behaviors are characteristic of infants with active alertness. The infant is fully awake, shifts eye focus from object to object, has full movement of limbs, and has increased vocalizations with a hint of fussiness.

The sixth and seventh levels represent the infant in a state of distress. The sixth level is alert agitation. During this level the infant is awake and fussy with irregular breathing patterns, leg extensions, side-to-side head movements, and crying. Crying is low stress level and the infant is easily comforted. The seventh level characterized by intense crying with facial color changes ranging towards red, tremor-like shaking of limbs, and difficulty comforting the infant.

These levels provide a concrete rubric for those interacting with infants and help to classify infants’ ability of self-organization by observations (Brazelton, 1973; Brazelton, 1984). Children can shift frequently and easily between stages within as little as a few seconds. Children may utilize self-regulating behaviors to calm themselves to stay within their ideal level and maintain attention on tasks like those involved with feeding. Although feeding for each infant is unique, the optimal level of alertness ideal for feeding is in stage four (Brazelton, 1973; Brazelton, 1984; Wolf & Glass, 1992).

Concepts of Self-Regulation and Self-Control

Self-regulation is a complex concept, suggesting the ability to comply with a request, respond to situations by initiating or ceasing activities, change intensity, frequency, or duration of an activity in various situations, and to behave according to social demands. Developmentally, children are incapable of complete self-regulation until preschool years; however, younger children can show signs of emerging skills. Early stages of self-initiated regulation can be expressed as forms of control and system organization, compliance, impulse control, and self-regulation (Kopp, 1982).

Developmental Stages of Self-Control

The 5 developmental stages of self-control have been identified as these stages: neurophysiological modulation, sensorimotor modulations, control, self-control, and self-
regulation (Kopp, 1982). With children under 2 years of age, the debate in the literature is whether or not cognition is developed enough to impact the child’s self-initiation of behavior. Given that children must be cognitively able to internalize a caregiver’s expectations before initiating self-regulation, external influences largely manipulate self-regulation behaviors in children less than two years of age. However, by demonstrating acts of sharing and expressing feelings of empathy, children as young as 15 months of age can produce patterns of behavior that are pragmatically appropriate (Kopp, 1982).

From late prenatal stages to 3 months of age, during the first developmental stage of self-regulation, infants are able to modify their level of alertness and to activate certain behaviors by means of neurophysiological maturation and modulation. Neurophysiological modulation, a form of control, is a combination of both neurophysiological and reflexive adaptations to environmental stimuli, which are portrayed as organized patterns of behavior. These patterns of behavior are often adaptive responses such as non-nutritive sucking to help reduce the arousal level of the infant. Variable integrity of the infant’s neurological system can lead to fluctuations in tolerable threshold levels of external stimuli. Additionally, the infant must continuously learn how to adapt to increases or changes in stimuli. Until he is able to ignore excessive stimuli, the infant may become focused on one specific stimulus source to compensate for this developing skill. Poorly adapted behaviors that lead to variable fluctuations of state levels of arousal are aided immensely when the caregiver provides relevancy to the events in the environment of the infant (Kopp, 1982).

The second stage of sensorimotor modulation occurs from 3 to 12 months of age and signifies the infant’s volitional motor movements and his ability to react to the environment. However, at this stage, the infant does not have cognitive intent or meaning as to why he is using specific motor movements. Self-regulating behaviors of the infant are initially demonstrated secondary to external stimuli. Extensive research has been conducted to determine how to separate infant motivation from perceptual processes. Although motivation will eventually impact an infant’s intentional movements, at this stage of development, other aspects of the environment will continue to play a role in the response to stimuli. The prominent learning lesson for infants at this
stage is how their own actions and movements differentiate from others. Realization of personal actions lends potential for the emergence of control (Kopp, 1982).

‘Control’ is characterized by the emerging responsive behavior of intentional, meaningful, and derivative movement and action of the infant. The third stage emerges in children 9 to 18 months or older. During this stage, the early signs of self-regulation are demonstrated by the infant complying with commands and/or requests in addition to self-initiated behavior. As the infant ages, cognition progressively increases in amount of impact. With the increase in cognitive abilities towards the end of the first year of life, sensorimotor functioning becomes less responsive and more intentional (Kopp, 1982). A primary example of cognitive influence on motor behavior is the change in upright positioning of the infant. Sitting prompts the initiation of walking and allows the infant to expand his spatial areas of exploration and lends to increased body functioning awareness (Kopp, 1982).

The final stages of self-control lending to self-regulation occur around 24 months of age and as a result, a sense of self is created for the infant. Adult consciousness develops from this sense of self (Kopp, 1982). Although prominent research exists for this area of development, because the age of participants in this study are below 18 months of age, the need for further examination of self-control and self-regulation is not necessary.

Optimal Positioning for Feeding

Positioning is a critical aspect to successful feeding. Positioning must be addressed with all infants in the early stages of development (Arvedson, 1998). The development of sitting allows for children to participate more independently in all activities. Uneven weight distribution affects midline positioning of the head and neck and creates pressure to constantly find center of gravity for children sitting incorrectly. As a result, the children become functionally restricted (Hong, 2005). Less than ideal quality in muscle tone and/or motor control will not only affect functional gross and fine motor skills, but can also adversely affect the postural alignment and consequently behavioral states, physiologic control, and oral-motor control (Glass & Wolf, 1998; Wolf & Glass, 1992). Central postural alignment includes neutral head flexion, neck elongated, shoulder girdle stable and depressed, trunk elongated, stable pelvis, hips at a
90 degree angle (not required for infants), and feet in a neutral position (Arvedson, 1998; Arvedson & Brodsky, 2002; Wolf & Glass, 1992). Therapists stress the importance of optimal positioning during feeding times. This positioning allows for a 90 degree angle at the hips and at the knees and requires the feet to be on the floor in a neutral position for children old enough to be sitting while eating (Arvedson & Brodsky, 2002). Pelvic stability and trunk control are documented to influence the position and control of the head and the alignment of oral structures (Redstone & West, 2004). In additional research, craniocervical posture has been proposed to be neurologically connected to pharyngeal patency, thus proving that proper head positioning will influence the act of swallowing and protect against aspiration (Redstone & West, 2004; Wolf & Glass, 1992). Therefore, without the stability of the pelvis, motor movements like tongue control and lip mobility will be impaired (Redstone & West, 2004).

Specific gross motor impairments of abnormal muscle tone, asymmetry and/or misalignment of the trunk or head, pelvic instability, and hyperextension of the head can result in oral motor impairments of jaw instability and depression, tongue retraction, and incoordination and lip retraction. These oral motor consequences may cause feeding disorders characterized by reduced food retention, poor mastication of food, delayed swallow, uncoordinated breathing and swallowing, and aspiration (Redstone & West, 2004).

Appropriate Usage of a Highchair

With the development of improved head and trunk control, infants approximately 6 to 8 months are appropriate for the use of a highchair (Arvedson & Brodsky, 2002; Redstone & West, 2004). While the use of commercial highchair is practical for many purposes because of the light-weight and attractive styles, these chairs often adopt a one-size fits all design. When working with typically developing or developmentally delayed children, customized seating and positioning systems may need to be utilized to create optimal positioning. Due to the expensive nature of custom seating devices, adaptations of a typical highchair regularly occurs using towel rolls, wedges, and cushions (Arvedson, 1998; Arvedson & Brodsky, 2002; Redstone & West, 2004).
Statement of the Problem

Although standardized tests and informal assessments exist for documenting sensory-processing impairments, these results do not measure how daily performances, like feeding, are affected (Dunn, 1997). Research documenting sensory-based feeding difficulties as a result of decreased input from the feet is non-existent. At this time the amount of pressure through the feet to generate effective sensory input is unknown. Studies have shown that tactile input helps children with sensory-processing disorders, yet the literature lacks investigation between children with feeding disorders in regards to sensory input through the feet. Formal research of self-regulating behaviors and how children, both typical and with disorders, focus their attention on feeding is important to keep them safe.

A child with a sensory-processing disorder may interpret feeding as an uncomfortable, painful, and/or upsetting event. However, as discussed, if deep pressure sensory input is occurring simultaneously, or quickly thereafter, as the feeding, the sensation of pressure will override the sensation of pain. Hypothetically, if a child is using his feet and pushing against an external source, deep pressure would be being applied to the soles of the feet, which may help to reduce feeding difficulties in sensory-based feeding etiologies. Current commercial market highchair products, however, are not designed to include an adjustable foot rest. The lack of a foot rest at an appropriate height leads to a child sitting in a highchair with his feet unable to rest on solid ground; thus not providing an outside boundary for the child to push against and receive sensory input through his feet. Research has shown that the attention and focus on action commands, like those involved in feeding, are affected when there is a withdrawal of sensory input (Cole, 2004). To compensate and achieve sensory input, a child may press his feet against the legs of the feeder or the tray of the highchair. In both of these scenarios, the child is gaining sensory input, but consequently, is not sitting in the optimal positioning for feeding, putting him at risk for feeding difficulties. Another consequence may be the caregiver becoming upset by this behavior, leading to a breakdown in the caregiver-child dyad.

Children with atypical development, especially involving muscle tone, motor control, and sensory-processing, can have adversely affected feeding situations (Glass &
Wolf, 1998). Children with feeding disorders will benefit from research involving sensory input from their feet; however, no normative data exists to compare the amount of foot pressures typically developing children use during feeding with atypical populations.

Purpose of the Study

This research project was a feasibility study aimed at observing typically developing children during meal times and to determine the amount of pressure exerted through their feet. More specifically, the purpose of this research project was to study trends between foot pressures and arousal levels/state behaviors during feeding. Because there is no literature looking at this issue, typically developing children ages 6-10 months and 12-18 months were recruited to determine normative data of foot pressures during feeding. This project intended to study the amount of pressure exerted through the feet using a prototype highchair, to observe children’s behaviors, and to study trends of how typically developing children self-regulate their attention and arousal levels during meals.

Hypotheses

1. The children who are walking are expected to have lower amounts of pressure exerted through their feet since they receive sensory input through their feet during the day. Younger children who are not walking are expected to have greater amounts of pressure to compensate for the lack of sensory input through their feet. The younger children are also expected to require more pressure to stay attentive than the older children.

2. During the feedings, children will utilize the footplate and increase foot pressures to maintain and/or increase attention and arousal.
CHAPTER II
Methods

Subjects

The subjects in this study were a sample of children ages 6 to 18 months of age recruited from the greater Cincinnati, Ohio and Indianapolis, Indiana areas. No attempt was made to sample for a subject’s gender, religion, ethnicity, or otherwise recruit minority populations. The participants were recruited by the researcher through a compilation of a list used in previous research studies which indicated that the families want to be contacted for future studies. The subjects were divided into two groups based upon the age and developmental stage of the child. Five children between 6 and 10 months of age who were not yet walking were called Group 0. Five children between 12 and 18 months of age and who were walking were called Group 1. For a child to be considered in Group 1, he or she must have been walking as the primary means of ambulating for a minimum of two weeks. Excluded from this study were subjects who had not met typical developing milestones for a child their age at the time of the study. Status for exclusion was determined by a screening questionnaire conducted by the researcher based upon information given by the caregiver of the subject. All aspects of this study were approved by Miami University’s Institutional Review Board prior to implementation.

Instrumentation

A prototype highchair was created by Dr. Michael Bailey-Van Kuren, Associate Professor in the Department of Mechanical & Manufacturing Engineering at Miami University (Figure 2). The highchair was originally a commercial chair produced by Evenflo© and was modified to have force sensing foot pedals. Each foot pedal had force sensitive resistors embedded into the pedals. The pedals were supplied by a 5 Volt source. The output voltage which passed through the resistors mounted within the foot pedals was sampled every second with a 16 bit data acquisition module connected to a 1.8 GHz Pentium 4 based laptop computer. The sampled output voltages for each pedal were recorded with the corresponding time stamps.
Design and Procedure

Testing for each subject consisted of 3 feeding trials lasting 5 to 15 minutes over the course of 2 weeks. Subjects were seated in the prototype highchair and their feet were strapped into plastic, orthopedic boots. Subjects were fed foods and/or drinks of their caregiver’s choice. No new smells, tastes or textures were introduced to the subjects. The study aimed to conduct one trial when the child was hungry, a second trial when the child had a decreased level of alertness, perhaps as the child was waking from a nap and a third conducted at a typical meal time for the child. The data was collected by a laptop computer connected to the footplate of the highchair. The caregivers were encouraged to remain with the subject throughout the duration of the study. The subjects were videotaped during the feeding trials to allow for observation of their behaviors. The researcher then coded each of the variables after watching the videos and synched the variables with the corresponding time stamps from the foot pedals.
Analysis

Descriptive analysis was used to analyze the data from this study. The amount of pressure exerted by the children was collected and then assigned a value of ‘pushing’ or ‘not pushing’ based on the average threshold of values. From there, certain behaviors, strategies, and variations in feeding trials were identified and coded from the video.

Research Questions

1. Do pushing behaviors (present/absent) relate to the age/developmental level of the child?
2. Are there differences between groups with respect to the length of time a child is in each specific awake state?
3. Are there differences between groups with respect to the percentage of pushing that occurs while in each specific awake state?
4. Are there differences between groups with respect to the percentage of pushing when certain behaviors are observed?
5. Are there differences between groups with respect to the length of certain observable behaviors?
6. Are there differences between groups with respect to the percentage of pushing when external strategies were used?
7. Are there differences between groups with respect to length of external strategies used?
8. Are there differences between groups with respect to the percentage of pushing depending on if the child is eating or drinking?
9. Are there differences between groups with respect to the length of eating or drinking?
CHAPTER III
Results
Descriptive Statistics

Subjects

Ten subjects from the greater Cincinnati, Ohio and Indianapolis, Indiana area were included in this study. The subjects were divided into two groups based upon the age and developmental stage of the child. Five children between 6 and 10 months of age who were not yet walking were called Group 0. Five children between 12 and 18 months of age and who were walking were called Group 1. The subjects in Group 0 ranged from 6 months, 6 days to 8 months, 17 days with a mean age of 7 months, 13 days (SD=31 days). The subjects in Group 1 ranged from 13 months, 0 days to 15 months, 24 days with a mean age of 14 months, 20 days (SD=32 days).

Research Questions

Research Question 1: Do pushing behaviors (present/absent) relate to the age/developmental level of the child?

On average in all three trials, Group 0 was observed to be pushing less than Group 1 (See Figures 3 and 4). Although only a small difference, older children at higher developmental levels displayed pushing behaviors more often than younger children at lower developmental levels during feedings.

Figure 3
Pushing Behaviors Related to Group 0 (6-10 months)

- Pushing
- Not Pushing

44%
56%

Figure 4
Pushing Behaviors Related to Group 1 (12-18 months)

Research Question 2: Are there differences between groups with respect to the length of time a child is in each specific awake state?

When comparing the two groups, Group 0 had a longer average trial length than Group 1 (See Figure 5). Subjects were only observed in attention and arousal levels 4, 5, 6 and 7. Differences were noted between groups as children in Group 0 were in calmer ranges of state behaviors, awake states 4 and 5, (Quiet Alert and Active Alert) more often (99.56%) than children in Group 1 (88.53%) throughout all three trials (See Table 1). No child in Group 0 reached a state level of 7, whereas one subject in Group 1 did.
Figure 5
Comparing Groups: Average Length of an Individual Trial

<table>
<thead>
<tr>
<th>Group</th>
<th>Time (Minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 0</td>
<td>8 m. 6 s.</td>
</tr>
<tr>
<td>Group 1</td>
<td>10 m. 29 s.</td>
</tr>
</tbody>
</table>

Table 4
Comparing Groups: Average Percentage of Time Spent in Awake States

<table>
<thead>
<tr>
<th>Awake State</th>
<th>Group 0</th>
<th>Group 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awake State 4 (Quiet Alert)</td>
<td>96.33%</td>
<td>81.34%</td>
</tr>
<tr>
<td>Awake State 5 (Active Alert)</td>
<td>3.23%</td>
<td>7.19%</td>
</tr>
<tr>
<td>Awake State 6 (Alert Agitated)</td>
<td>0.48%</td>
<td>5.51%</td>
</tr>
<tr>
<td>Awake State 7 (Crying)</td>
<td>N/A</td>
<td>5.96%</td>
</tr>
</tbody>
</table>

Research Question 3: Are there differences between groups with respect to the percentage of pushing that occurs while in each specific awake state?

Overall, Group 1 had higher pushing percentages in all states except awake state 6 (Alert Agitated). Figures 6 and 7 graphically display the average foot pressure percentages by both feet, one foot, and no feet for Group 0 and Group 1, respectively, for
all trials. Table 2 shows combined both feet and one foot average percentages are for all three trials.

Figure 6
*Group 0: Comparing Pushing Percentages by Feet in Awake States*
Figure 7

Group 1: Comparing Pushing Percentages by Feet in Awake States

Table 5

Comparing Groups: Combined Average Foot Pressure Percentages in Awake States

<table>
<thead>
<tr>
<th></th>
<th>Group 0</th>
<th>Group 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awake State 4</td>
<td>74%</td>
<td>76%</td>
</tr>
<tr>
<td>(Quiet Alert)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awake State 5</td>
<td>47%</td>
<td>80%</td>
</tr>
<tr>
<td>(Active Alert)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awake State 6</td>
<td>90%</td>
<td>83%</td>
</tr>
<tr>
<td>(Alert Agitated)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awake State 7</td>
<td>N/A</td>
<td>59%</td>
</tr>
<tr>
<td>(Crying)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Research Question 4: Are there differences between groups with respect to the percentage of pushing when certain behaviors are observed?

When comparing groups and behaviors, Group 1 pushed more often with both feet than Group 0 in all behaviors except coughing (See Figure 8).

Figure 8
*Comparing Groups: Average Pushing Percentages When Certain Behaviors are Observed*

<table>
<thead>
<tr>
<th>Behavior</th>
<th>Group 0 - Coughing</th>
<th>Group 1 - Coughing</th>
<th>Group 0 - Throwing Food</th>
<th>Group 1 - Throwing Food</th>
<th>Group 0 - Pushing Food Away</th>
<th>Group 1 - Pushing Food Away</th>
<th>Group 0 - Arching</th>
<th>Group 1 - Arching</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>46.43</td>
<td>33.33</td>
<td>33.33</td>
<td>47.62</td>
<td>18.42</td>
<td>31.82</td>
<td>37.28</td>
<td>45.32</td>
</tr>
<tr>
<td></td>
<td>32.86</td>
<td>33.33</td>
<td>66.67</td>
<td>29.17</td>
<td>36.84</td>
<td>36.37</td>
<td>22.43</td>
<td>17.32</td>
</tr>
<tr>
<td></td>
<td>20.72</td>
<td>33.33</td>
<td>0.00</td>
<td>44.74</td>
<td>44.74</td>
<td>31.82</td>
<td>40.30</td>
<td>37.36</td>
</tr>
<tr>
<td>Two Feet</td>
<td>One Foot</td>
<td>No Feet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Percentage of Time

Research Question 5: Are there differences between groups with respect to the length of certain observable behaviors?

Small differences in length of behaviors were noted between groups when observing the following behaviors in a trial: throwing food, coughing, pushing food away, and arching of the back (See Figure 9). Overall, Group 1 had lesser lengths of behaviors than Group 0.
Research Question 6: Are there differences between groups with respect to the percentage of pushing when external strategies were used?

When comparing groups for pushing percentages with both feet, only small differences are noted when a caregiver was talking to the child. However, Group 1 used both feet more when the strategy being used was touching (See Figure 10).
Research Question 7: Are there differences between groups with respect to length of external strategies used?

In a trial, caregivers touched children in Group 0 for longer periods of time than those in Group 1 (See Figure 11). However, caregivers talked longer to the children in Group 1 than in Group 0. Other external strategies, using a pacifier, playing with toys, and watching television, were used during trials, however, only by one group, so no comparisons were made.
Research Question 8: Are there differences between groups with respect to the percentage of pushing depending on if the child is eating or drinking?

There did not appear to be notable differences of pushing percentages between groups depending on whether a child was eating or drinking (See Figure 12).
Comparing Groups: Average Pushing Percentages While Eating and Drinking

Research Question 9: Are there differences between groups with respect to the length of eating or drinking?

Group 0 had significantly longer periods of eating than Group 1. Average length of drinking behaviors was also longer for Group 0 (See Figure 13).
Figure 13

Comparing Groups: Average Length of Eating and Drinking

Group 0 - 10 min. 29 sec.
Group 1 - 8 min. 6 sec.
CHAPTER IV
Discussion

Result Findings

The present study investigated typically developing children at distinctly different developmental levels and aimed to determine any correlations between foot pressure and arousal/attention levels during feeding trials. The data found refutes the first hypothesis that the older children in Group 1 would push less through their feet during feeding than children in Group 0. Instead, the data showed that the older children who were walking (Group 1) pushed 59% of the time compared to the younger children who were not walking (Group 0) at 56% of the time (See Figure 1). One possible explanation may be because children who are walking receive sensory input through their feet on a consistent basis, they have adapted to using this input to help self-regulate themselves on a more continuous basis. The data appears to show that as children begin receiving sensory input through their feet, they rely on the input throughout various events of the day.

Another interesting finding was that children in Group 1 consistently used both of their feet when pushing more than the children in Group 0. When comparing the amount of pushing percentages in each awake state (See Figure 7), the older children used both feet to push at least 49% of the time while in each of the awake states. The graphs in Figure 6 show that the younger children inconsistently used both feet resulting in a varied amount of pressure ranging from 28% to 63%. Because younger children’s developmental motor systems are less refined, inconsistent usage of both the feet is expected to some extent, however; the data also supports the idea that younger children have not yet developed the skills of utilizing their feet to self-regulate as well as older children. When looking at the total pressure pushed by each group, similar trends were noted as each group increased pressure percentages when levels of agitation increased (See Table 4). Group 0 was inconsistent in increasing the pressure percentages at each level, but overall increased their pressure percentages from 74% to 90%. Group 1 was very consistent in increasing their pressure percentages from 76% to 80% to 83% as levels of agitation increased.

When comparing pushing percentages during certain behaviors (See Figure 9), the older children in Group 1 used both feet to push more than the younger children in all but
one of the behaviors (e.g. coughing). All of the behaviors observed in this study were some form of food refusal, which is important to note because often along with food refusal, children become fussy and agitated. Three of the behaviors, arching, pushing food away, and throwing food, provide external tactile input, whereas coughing is an internal sensation and does not provide any external sensory input. Interestingly, the older children used both feet to push more often than the younger children when arching, pushing food away, and throwing food, all behaviors involving additional external tactile sensory input. This difference may be attributed to the idea that older children have learned to incorporate their own self-regulating behaviors when provided some external tactile sensory input. The pushing of both feet of the older children when added to the tactile input provided by these three behaviors appeared to shorten the length of refusal behaviors during feeding. When the average number of seconds from each of these three behaviors in a trial is combined (See Figure 8), the older children had a total of 6 seconds whereas the younger children had a total of 11 seconds.

Another area where the older children (Group 1) pushed with both feet more than the younger children (Group 0) was when external strategies were used by the caregiver to calm the child (See Figure 11). There was hardly any difference in pushing percentages between groups when caregivers were talking. However, when caregivers used touch as a strategy, the older children pushed with both feet more than the younger children (61.75% and 42.73% respectively). Also, when comparing the pushing percentages of Group 1 of both feet between talking and touching, a large increase in pushing during touching was noted. This increase may be attributed to the older children responding to touch by enlisting their own self-regulating behaviors of pushing with both feet, resulting in less help needed from the caregiver. Although correlations between arousal levels and strategies cannot be made at this time, the data appears to show that older children require less time from the caregiver to calm down. By looking at the length of external strategies used by a caregiver in a trial (See Figure 10), the older children had less time of help (39 seconds) than the younger children (45 seconds). Specifically, when the older children were provided external tactile sensory input (e.g. touch) by the caregiver, they required only 14 seconds of help compared to 36 seconds in
the younger children. The data also shows that caregivers are more likely to touch younger children and more likely to talk to older children.

When comparing the groups, the younger children had a longer average trial of 10 minutes, 29 seconds versus 8 minutes, 6 seconds for the older children (See Figure 5). When looking at feeding, the younger children (Group 0) were either eating or drinking 100% of the time during a trial (See Figure 12). The older children (Group 1) had on average 2 minutes, 20 seconds of not eating or drinking during a feeding trial. However, as children age, a shorter feeding period may be common as they become more interested in other stimuli and have decreased attention during feeding (Arvedson & Brodsky, 2002). When looking at pushing percentages (See Figure 13), no major differences were found between pushing with both feet for either of the groups.

The data from this research is consistent with the proven facts that external tactile sensory input is calming and that children seek external sensations as a calming mechanism (Ross, 2007; Satter, 1990; VandenBerg, et al. 2003). Research has shown that young children use self-regulation behaviors involving their feet for isolated incidents of stress (Ross, 2007), but this research also proposes the new idea that as children begin walking and receiving more sensory input through their feet, their patterns of self-regulation mature and foot pressing behaviors are used more consistently rather than in isolated incidents only. As a result, older children continue to seek external boundaries to receive sensory input through their feet while feeding to possibly help with self-regulation. Because the younger children have not yet been exposed to a consistent amount of sensory input through their feet, they have not learned how to utilize their feet to self-regulate as well. While children become more independent as they age, the caregiver is still important in providing structure during feeding times (Arvedson, 1997; Arvedson & Brodsky, 2002). A new finding from this study may indicate that caregivers should provide some tactile sensory input to serve as a reminder to older children to enlist their own self-regulation of foot pressing behaviors. In summary, the older children pushed more than the younger children during feeding trials. The older children also pushed with both feet more consistently and more often and resulted in less time of refusal behaviors and help from the caregiver, supporting the idea that as children age they learn to use their feet more to self-regulate.
**Limitations**

Inherent to a feasibility study, the small number of subjects (10) was a limitation and precluded the use of statistical analysis. Further, some amount of malfunction of the highchair must also be appreciated. Of the 30 trials, 5 had to be excluded due to incomplete data collection from the foot pedals. Another variable that could not be controlled for was caregiver interaction with the children. By wanting the children to be as comfortable and as natural during the feeding trial as possible the researcher did not conduct the actual feeding trials. Caregivers conducted the feeding trials and the differences in their tone of voice, type of touching, and type of food was not controlled. Finally, because of the small sample size, only the researcher was involved in identifying specific arousal/attention levels, behaviors and strategies.

**Future Research**

Future research continuing this study is needed to address several variables. This study did not determine how much pressure or force through the feet was used. Once a more refined highchair with more specific technology to collect exact pressure values is designed, exact amounts of pressure can be determined for each group of children. Future research with larger subject groups would allow for more statistical analysis of the variables examined in this study.

Examining the time of day that feedings occur is another area not yet researched. Potential research questions could include: Are there differences between groups with respect to the percentage of pushing that occurs depending on what time of day the feedings occur and are there differences between groups with respect to the length of time a child pushes depending on what time of day the feedings occur.

Another area that would benefit from future research would address the second hypothesis posed in this study. The second hypothesis stated that during the feedings, children will utilize the footplate and increase foot pressures to maintain and/or increase attention and arousal. After conducting this study and analyzing the data, future research is needed to support this hypothesis. Although the data showed that increased foot pressure in the older children resulted in less occurrences of food refusal behavior, the link between behaviors, external strategies, eating/drinking and arousal levels can not be
made at this time. However, several initial trends were found related to the transitions between awake state levels and foot pressures.

When comparing the graphs for percentage pushing across all trials in both groups (See Figures 6 & 7), at awake state 6 (Active Alert), similar percentages of pushing through the feet can be observed. As children became more agitated and reached higher levels of awake states, they began pushing with their feet more often. Both groups had the highest combined percentage of pushing at the awake state 6 (Alert Agitated) with 90% for Group 0 and 83% for Group 1. Future research of children at an arousal/attention level of 7 (Crying) could provide more insight into whether this trend of foot pressing increasing with arousal levels is consistent.

When arousal levels were graphed in sync with combined foot pressures, the trend of an older child using foot pressures to calm himself was seen. Figure 14 shows one trial of a child in the older group (Group 1). By looking from 20 seconds into the trial to the end, three predictions can be made about using foot pressures when transitioning between awake states. First, at 32 seconds, the child drops from an awake state of 7 (crying) to 4 (quiet alert). In the 12 seconds before this transition, the child begins pushing with both feet for majority of the time. This pattern of pushing with both feet for an extended period of time during a period of agitation may be the trigger in transitioning from a level of crying to a level of increased attention and quiet alertness. Secondly, between 32 and 60 seconds, the child is consistently pushing with both feet. At first there is a period of 12 seconds of maintained calmness and attention before becoming agitated again. After reaching a level of 7 (crying) again, the child continues to push with both feet, which leads to a stair-step configuration of decreasing agitation and increasing attention and calmness. Finally, around 60 seconds, the child stops pushing with one foot, resulting in an increase of agitation a few seconds later. This trend is also observed around 84 seconds when the child stops pushing all together, and he jumps from a level 5 (active alert) to a level 7 (crying). Throughout the rest of the trial, the child appears to be unable to consistently use foot pressures to manage his arousal and attention levels. Future research is needed to find more patterns similar to this observed trend.
Conclusion

In conclusion, the data from this study provides an abundant amount of information regarding typically developing children and specific variables during feeding. The results show that older children need to have the opportunity to self-regulate themselves by using their feet to push. Younger children also need the opportunity to experiment with self-regulation through the feet. Even though Group 0 was expected to not have consistency with pushing through their feet, they still demonstrated pushing behaviors throughout the trials, proving that the younger children were trying to figure out what is needed to self-regulate. Because children in this age range (6-18 months) go through numerous developmental changes (i.e. sitting, pulling to stand, standing, walking, jumping), variations in pushing behaviors were expected. Children also go through new feeding experiences during this age range as they progress from bottle/breast feeding, to finger foods, to table foods, to new textures and
consistencies, to using fingers, to using eating utensils. Advancing through these stages can be a sensory-overloaded experience and children need to have the opportunity to use self-regulating techniques to help them learn to accept new foods. To give children this chance, they need to be provided a highchair that gives the appropriate support to allow the children to self-regulate. This highchair needs to have adjustable foot plates that fit each child appropriately. If a highchair of this kind is unavailable, then the caregiver should provide an alternative structure for pushing (i.e. caregiver’s legs). However, the caregiver should be aware that the pushing behaviors the children exhibit are not negative behaviors, but something they need to help regulate themselves. The data also suggests that perhaps caregivers should give some tactile “reminder” to the older children as a means of initiating the foot pushing behaviors. Finally, abundant future research is needed to continue to make correlations between pushing behaviors and attention and arousal levels in typically developing children before the results can be applied to children with sensory-processing difficulties during feeding.
References


Appendix A

REVIEW OF THE CENTRAL NEUROUS SYSTEM AND PERIPHERAL NEUROUS SYSTEM

1. **Central Nervous System (CNS)** – The CNS is comprised of:
   a. **Brain** – Two cerebral cortices serve as the operator
   b. **Spinal Cord** – A cord running vertically serves as the transmitter. The spinal cord is a combination of gray and white matter surrounded by protective vertebrae (See Figure 15).

![Cross-sectional View of the Spinal Cord](image)

Figure 15

*Cross-sectional View of the Spinal Cord*

In this cross section view, note that the gray matter is a butterfly shape surrounded by white matter. The differentiations of the dorsal and ventral horns of the gray matter function as sensory and motor paths, respectfully. All sensory fiber cell bodies join at the dorsal root ganglion before the axons ascend towards the brain within the dorsal horn of the spinal cord (Vander et al., 2001; Zigmond et al., 1999). Afferent neurons do not synapse with any other neuron before the axon enters the brain and so afferent neurons can also be called first order neurons or primary afferents (Vander et al., 2001).

2. **Peripheral Nervous System (PNS)** – Forty three pairs of nerves comprise the PNS. Of the 43, 31 are spinal nerves origination from the spinal cord and 12 are named cranial nerves because of their origins being within the cerebrum. The
cranial nerves are either sensory only, motor only, or mixed (both sensory and motor) in purpose. In some instances the cranial nerves relay information for specialized senses like olfaction, vision, hearing and balance and taste (Zigmond et al., 1999). Thirty one pairs of spinal nerves extend from the spinal cord and are responsible for all motor movement and sensory information from the body.

a. **Afferent** - When stimulation originates from within skin, skeletal muscles, tendons and joints, or outside of the body, somatic afferents are the neurons that bring the message to the CNS (Zigmond et al., 1999).

b. **Efferent** - The efferent division can further be divided into the somatic nervous system and autonomic nervous system (ANS). The somatic nervous system is comprised of peripheral nerves carrying efferent information from the skeletal muscle cells synapse with a single neuron to travel to the CNS.

i. **Somatic Nervous System**

ii. **Autonomic Nervous System** - The autonomic division of the PNS has a chain of two neurons between the CNS and organs. These neuronal chains are comprised of networks of neurons that control peristaltic movements within the digestive system, secretion control of the digestive tract, a control of blood vessel constriction in addition to other controls of deep organs (Zigmond et al., 1999).