Pilot Study Investigating Infant Vagal Reactivity and Visual Behavior During Object Perception

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OBJECTIVE. The authors examined whether changes in vagal tone were related to infant visual attention during auditory and visual events paired (synchronous) and not paired (asynchronous) in time. They predicted that infants would demonstrate greater visual attention to the synchronous slideshow and that vagal tone would decrease with visual attention.

METHOD. Nineteen infants, 3.5 months old, watched computer-generated synchronous or asynchronous slideshows of auditory and visual stimuli. Visual behavior and vagal tone data were collected. Vagal tone reflects physiological responses during attention or exposure to mild stressors. Repeated-measures analysis of variance examined differences in vagal tone across conditions.

RESULTS. Visual behavior did not differ between the synchronous and asynchronous slideshow conditions. Vagal tone was significantly lower during the asynchronous slideshow.

CONCLUSION. Infants may discriminate synchronous from asynchronous stimuli without changing visual behavior. Implications related to play with toys or objects are discussed.

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The notion that sensory stimuli become integrated through interaction with the environment is a basis for clinical reasoning in pediatric occupational therapy (Ayres, 1979; Koomar & Bundy, 2002). Historically, therapists using a sensory integration approach based their treatments on the premise that proprioceptive, vestibular, and tactile systems are the "cornerstone" sensory systems that become integrated through experience (Koomar & Bundy, 2002, p. 262). More recently, therapists are evaluating how multiple sensory systems, including the visual and auditory systems, contribute to engagement in school, play, and activities of daily living (Henderson, Pehoski, & Murray, 2002). Sensory integration theory provides a conceptual foundation explaining the interaction between sensory systems to produce functional outcomes. For example, the visual system functions cooperatively with other sensory systems to facilitate reaching, grasping, movement, and locomotion (Henderson et al., 2002). The auditory system is recognized as providing a foundation in human performance, and "clinicians are again beginning to recognize the need to situate the auditory system in their study of sensory integration" (Burleigh, McIntosh, & Thompson, 2002, p. 141).

Akin to sensory integration is the field of intersensory perception. Research in the field of intersensory perception provides insights into infants' capacity in processing temporal aspects of visual and auditory information (Bahrick & Lickliter, 2000; Gibson & Pick, 2000; Lewkowicz, 2000; Morrongiello, Fenwick, & Chance, 1998). Attributes of the stimuli (e.g., *temporal synchrony,* or paired sights and sounds) provide the basis for perceptual development, learning, and cognition (Lewkowicz, 2000). Once infants perceive temporal synchrony, they

begin to understand other temporal and spatial relationships inherent in objects including rate, rhythm, duration, location, and pitch (Bahrick & Lickliter, 2000; Gibson & Pick, 2000; Lewkowicz, 2000; Morrongiello et al., 1998). Temporal synchrony can be equivalently perceived by the visual and auditory systems and is a basis or precursor for language and cognitive development (Gibson & Pick, 2000; Lewkowicz, 2000). For example, before infants are able to detect the rhythm of a ball bouncing, they must first perceive the synchrony between the sight of the ball hitting the ground and the concurrent sound. Temporal synchrony of auditory and visual stimuli is also consistent with the construct of intersensory redundancy (Bahrick & Lickliter, 2000).

Intersensory redundancy occurs when two stimuli are presented concurrently (Bahrick & Lickliter, 2000). The intersensory redundancy hypothesis predicts that when visual and auditory stimuli are presented simultaneously, infants develop the ability to understand their environment. When redundant information is presented across two sensory modalities (auditory and visual), visual attention to the synchronous stimuli increases. Subsequently, infants screen out extraneous information and develop a unified perception of a complex stream of multimodal events. By being more attentive to redundant stimuli, infants are able to tune out irrelevant stimuli. Understanding the types of stimuli that promote attention in infancy is important to occupational therapists because this knowledge may affect choices of toys during infant play.

To measure the effects of redundant sensory stimuli on perceptual learning, Bahrick and Lickliter (2000) tested 5-month-olds' ability to discriminate rhythm when stimuli were presented bimodally (auditory and visual) and unimodally (auditory or visual). Infants were unable to detect changes in rhythm when the information was presented unimodally, whereas they were able to detect changes in rhythm when the information was presented across the auditory and visual systems simultaneously. These findings suggest that synchronous auditory and visual stimuli are salient in infancy and that detection of temporal synchrony may be a precursor to perception of other temporal characteristics such as rhythm. Therefore, typically developing infants may prefer toys that light up when a sound is emitted, and this preference may lead to the development of refined perception.

Consistent with the intersensory redundancy hypothesis, we predicted that infants between ages 3 and 4 months would look longer at paired sight–sound stimuli (synchronous) than at unpaired sight–sound stimuli (asynchronous) and that visual attention to stimuli would be accompanied by physiological responses also thought to reflect attention (Doussard-Roosevelt & Porges, 1999; Porges, 1995).

Previous research has shown that infants prefer synchronous stimuli; however, little evidence demonstrates physiological changes to redundant or paired stimuli. Consistent with previous research using measures of vagal tone and measures of attention (Porges, 1995), we predicted that changes in the autonomic nervous system would accompany attention processes and support the overt behavior of visual gaze. Measures of vagal tone are indirect measures of autonomic nervous system influences on the heart and are associated with psychophysiological processes, such as sustained attention and the influences of mild stressors (Porges, 2001; White & Porth, 2000).

Heart Rate Variability, Vagal Nerve Reactivity, and Intersensory Perception

The autonomic nervous system modulates beat-to-beat changes in heart rate within the respiratory cycle, and fluctuations in heart rate associated with the respiratory cycle are known as respiratory sinus arrhythmia (Berntson, Cacioppo, & Quigley, 1993; White & Porth, 2000). Respiratory sinus arrhythmia is an indirect measure of vagus nerve influences on the sinoatrial node of the heart and is identified in the literature as vagal tone (Porges, 2001). Measures of vagal tone that arise from the fluctuations in heart rate as a result of breathing provide quantification of modulations in heart periods (duration of one beat; White & Porth, 2000). As vagal output (tone) increases, heart rate becomes slower and beat-to-beat interval variability increases. Conversely, as vagal output (tone) decreases, heart rate becomes faster and beat-to-beat interval variability decreases (Akselrod et al., 1981; White & Porth, 2000).

The polyvagal theory (Doussard-Roosevelt & Porges, 1999; Porges, 1995) suggests that reduced vagal tone is associated with increased attention. Porges (1974) examined respiratory sinus arrhythmia in newborns following presentation of noncontingent auditory stimuli and found that vagal tone decreased during sustained attention. Extending the work of Porges (1974), Richards (1987) found that changes in heart rate were associated with sustained looking in infants at ages 14, 20, and 26 weeks.

These earlier studies provided the basis for the findings presented in this study. Our aim was to examine whether infants who were more attentive to synchronous stimuli would have associated physiological responses. Specifically, we examined the relationship between infants' abilities to visually attend to object characteristics (temporal synchrony and asynchrony) and physiological responses. Infants' behavioral and physiological responses during two conditions are reported. The two conditions were object perception conditions in which infants viewed geometric shapes

on a computer screen and heard sounds that occurred simultaneously or separately.

In keeping with the intersensory redundancy hypothesis, we hypothesized that when 3.5-month-old infants were presented with two separate slideshows (synchronous and asynchronous), they would exhibit greater visual attention and reduced vagal tone during the synchronous slideshow than during the asynchronous slideshow. Dependent measures reported herein include infant looking behavior and infant vagal tone.

Method

Study Design

The findings reported herein are part of a larger study examining how infants' behavioral and physiological capacities are related to maternal child-bearing attitudes and maternal interaction styles (Barnekow, 2003). Data were collected to examine whether infant behavioral and physiological responses during the conditions were significantly different and are reported. In addition, mothers completed a questionnaire pertaining to maternal child-bearing attitudes and perceptions of infant temperament (Pizur-Barnekow, 2006).

Participants

Participants were recruited from childbirth classes, mother support groups, and pediatric clinics in the Midwest. Approximately 400 recruitment brochures were left in clinic reception areas. Mothers attending childbirth classes and mother support groups were personally invited to participate. Twenty-one mothers volunteered to participate in the study and were personally invited. Mothers received a $15 grocery certificate for their participation. Approval was obtained from the University of Wisconsin–Madison institutional review board.

Mothers were included if the child was their first birthing experience, they were married or living with a partner, and they were not taking prescription medications for physical or emotional reasons at the time of the study. One mother had premature triplets, so their data were excluded because of environmental confounds. One mother did not agree to participate in all parts of the study. The exclusions yielded a sample of 19 mother–infant dyads who participated in the study.

Infants were included if their mothers reported no significant history of visual, hearing, or neurological disorders. Infants were tested between the chronological ages of 14 weeks and 17 weeks, because infants of that age have the postural control to support visual attention and are typically not fluent in object manipulation.

Procedure

Materials. These included physiological and behavioral measures.

Physiological measures. Electrocardiogram data for analyses of vagal tone were collected using a five-lead Holter recorder (series 8500, Marquette Electronics, Milwaukee, WI). A small digital clock was used to denote the beginning and end of conditions. Five silver chloride electrodes were placed using a standard five-lead Holter configuration.

Behavioral measures. Two JVC digital video cameras (model GR–DVP3) mounted on tripods were used to record behavioral data. A PC notebook with a 14-in. screen (diagonal measurement) was used to display the infant slideshows. Infants were positioned in an infant seat on the floor, 60 cm away from the computer screen. One video camera recorded the infant's visual gaze and was placed 76 cm away from and directly in front of the infant. When the infant was viewing the slideshow, the mothers sat to the side and behind the infant, outside the infant's visual field.

Visual Stimuli. Two slideshows consisting of arbitrary artificial visual and auditory stimuli were created in PowerPoint (Microsoft Office 2000 Standard Version). The slideshows were originally developed for this study. The stimuli were developed through previous research (Lewkowicz, 2000); however, they were not direct replications of stimuli used in that research. Stimuli were black and imposed on a white background. Infants are attracted to visual stimuli that incorporate high-contrast designs (Fantz, 1963). The height of the stimuli varied according to shape: circle height, 3.5 in.; rectangle height, 2 in.; and triangle height, 4.5 in. Both slideshows included a pre- and postimage consisting of a four-point star (5 in. × 5 in.), centered on the screen and paired with a sound similar to the sound of applause. The appearance of the four-point star marked the beginning and end of the show for coding purposes.

Following the preimage, computer-generated shapes moved across the screen in a sequence. First, a circle shape moved from the top to the bottom of the screen. Second, a rectangle moved from the bottom to the top of the screen, and finally a triangle moved from left to right. The movement of the triangle differed from the circle and rectangle in that the movement was punctuated rather than progressive and fluent. Research has shown that infants prefer objects that move fluently through space more than static representations of objects (Lewkowicz, 1992).

Both synchronous and asynchronous slideshows were shown to the infants. The synchronous slideshow was 2 min, 2 sec, in length, and the asynchronous slideshow was 2 min, 1 sec. Figure 1 provides a graphic representation of the slide-
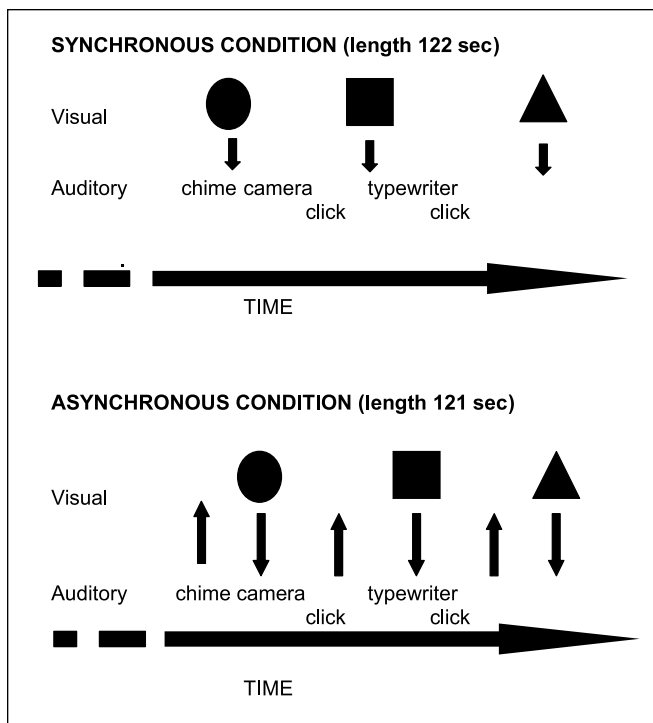
Figure 1. Timing and sequence of the synchronous and asynchronous slideshows.

Note. Visual images were present 18.17 sec (synchronous) and 19 sec (asynchronous).

shows. Each slideshow was predictable in that the order of the shapes and sounds did not vary. Visual images during each slideshow were shown for a relatively consistent period of time, with the asynchronous visual display lasting for 18.17 sec and the synchronous display lasting for 19 sec. Slideshow presentation order was counterbalanced.

During the synchronous slideshow, each shape was paired with a distinct sound. The circle was paired with a chime, the rectangle with a camera click, and the triangle with a typewriter click. The duration of the sight–sound pairing was approximately 2 sec, and the onset of the visual and auditory stimulation was synchronized.

During the asynchronous slideshow, shapes and sounds were separate and distinct. The visual image was presented first, and it was displayed for approximately 2 sec. There was a 1-sec time differential between presentation of the visual image and presentation of the auditory stimulus. This delay was supported by Lewkowicz (2000); he found infants detected asynchrony when auditory and visual information were separated by at least 350 msec.

Experimental Procedures. Mothers recruited as described were asked to mail a form confirming their interest in the study. Mothers were then contacted by telephone to describe the study and to determine eligibility. An appointment for a home visit was scheduled, corresponding to the infant age of 16 weeks (±10 days).

On arrival, experimental procedures and sequence were explained to the mothers, and informed consent was obtained. Grocery certificates were provided to participating mothers after consent forms were signed. Mothers identified a room in the home where the equipment could be set up. Infant respiratory rates were determined by palpating the infant's chest for 30 sec and multiplying the number of respiratory cycles by two. The infant's skin was prepared for electrocardiogram electrode placement by cleansing skin areas with an alcohol swab to remove body oils and drying with a washcloth. Electrodes were placed on the infant's chest using a two-channel, five-electrode configuration (GE Medical Systems, Wauwatosa, WI), and electrocardiogram data were continuously recorded until the experimental session was completed. After the electrodes were attached, the remainder of the experimental equipment was set up. The infant was placed in the infant car seat, and the seat belt was fastened.

During the baseline period, mothers were instructed to play with their infant as they normally would for 3 min. After the baseline, the infant viewed either the synchronous or the asynchronous slideshow. Following the slideshow, mothers were instructed to resume play with the infant for 3 min. This time period allowed the infants to engage in an activity different from the visual stimulus and decreased the likelihood of carryover effects from the first slideshow condition. After the second play, infants viewed the alternate slideshow (synchronous or asynchronous). Mothers were allowed to provide the infants with a pacifier during slideshows if they were becoming irritable. Infants were randomly assigned to begin with either the synchronous or the asynchronous condition. The electrocardiogram leads were removed from the infant on completion of the experimental procedures.

Methods of Quantification: Heart Rate Variability and Vagal Tone. Infant electrocardiogram data were collected by Holter recorders, uploaded, and digitized at 128 Hz by means of a MARS 5000 Holter analysis system (Marquette Medical Systems, Milwaukee, WI). Each recording was examined, and electrocardiogram complexes were labeled and categorized as to morphology. A trained PhD-level registered nurse visually reviewed each recording to identify sequences of artifact or mislabeled electrocardiogram complexes in the data. Missing or noisy data were identified and quantified, and any recording with more than 10% unusable data was excluded from the analysis. Interbeat intervals between successive normal complexes were determined, and only sinus electrocardiogram complexes were used in the final analyses (White & Porth, 2000).

Frequency domain measures of heart rate variability were determined by means of power spectral analysis. Power spectral analysis uses mathematical computations to model patterns found within the electrocardiogram signal. The outcome

of power spectral analysis is identification of frequency components of variance associated with heart rate variability (Bernston et al., 1993). Power spectral analysis provides information about the variability between R–R peaks of the cardiac cycle recorded on the electrocardiogram that result from periodic oscillations of heart rate at various frequencies. The high-frequency band, which is associated with changes in respiration, appears to originate exclusively from the parasympathetic nervous system (Akselrod et al., 1981) and was used to determine vagal tone responses during study conditions.

In adults, the high-frequency band typically extends from 0.15 to 0.40 Hz. Given the infants' more rapid respiratory rate, however, a frequency range of 0.15 to 1.15 Hz was used to capture the full width of the respiratory sinus arrhythmia. The specific bandwidth was determined for each infant on the basis of his or her individual respiratory rates. The range of respiratory rates was 30 to 70 breaths per minute. All infants were within the average range typically seen at 3.5 months (30–80 breaths per minute; Petry & Rainville, 1999). Vagal tone measures were quantified for continuous 60-sec intervals during each experimental condition (baseline, first and second play, synchronous and asynchronous slideshow, and postcondition measures). Means were calculated from these 60-sec measures for each condition outlined, and these means were used in the analyses.

Behavioral Recording, Coding, and Reliability. Three measures of infant looking were quantified (total duration of looking, frequency of looks, and frequency of sustained looking). *Sustained looking* was defined as a look lasting longer than 5 sec (Porges, 1974; Richards, 1987). *Frequency of looks* was the total number of times the infant fixated on the stimuli in a given session, and *total duration of looking* was the total number of seconds the infant fixated on the stimuli. Visual behaviors were coded from videotape by Kris Pizur-Barnekow (the principal investigator), who was unaware of treatment conditions. A graduate student (unaware of the hypotheses and treatment conditions) coded 30% of the tapes for interrater reliability analyses. Interrater reliability coefficients were .93 (total duration of looking), .96 (frequency of looks), and .86 (frequency of sustained looking).

Statistical Analyses. Mean differences in looking behavior (duration of looking, frequency of looks, frequency of sustained looking) across the two slide shows (synchronous, asynchronous) were evaluated using repeated-measures analysis of variance (ANOVA). Because participants serve as the control, the repeated-measures ANOVA reduces the magnitude of the error term found in ANOVA and is a more powerful test (Portney & Watkins, 2000). A Greenhouse–Geisser correction was used as a statistical correction for unequal variances and decreased the potential for committing a Type I error (Portney & Watkins, 2000). Relationships among variables were evaluated using the Pearson product–moment correlation.

Results

The mean age of the mothers was 30 years (range = 22–39 years). Reported annual household income ranged from $30,000 to $100,000. Maternal education level ranged from some college to graduate school. Of the 19 mothers, 7 were not employed outside of the home, and 12 were employed either full- or part-time. The sample primarily consisted of Caucasian women (95%).

Electrocardiogram data for 6 infants were lost because of malfunctioning lead wires, resulting in recordings that did not produce a clear signal. Thus, data from 13 full-term infants are reported in the repeated-measures ANOVA. These participants included 8 boys and 5 girls. The mean gestational age was 40 weeks ($SD = 0.93$), birthweight was 8 lb ($SD = 0.83$), and chronological or adjusted age when tested was 15 weeks ($SD = 0.97$; range = 14 to 17 weeks). One infant was excluded from the intercorrelation analyses ($n = 12$) because the infant's change in vagal tone over time was significantly different from that of the other infants.

Infant Looking Behavior

No significant differences were found in infant looking behaviors across the two conditions for total duration of looks, frequency of looks, or frequency of sustained looking.

Physiological Data: Infant Vagal Tone

Figure 2 shows that, even though no differences were found in infant looking behavior across the slideshow conditions, significant changes in vagal tone occurred. Vagal tone was lowest during the asynchronous slideshow and highest during the synchronous slideshow [$F(1, 12) = 6.91$, $p = .02$]. Vagal tone values across participants between conditions were all significantly intercorrelated with one another (rs = .76 to .93, ps < .05 to .001).

Looking and Vagal Tone Data

No significant correlations were found between the three measures of infant looking behavior and mean vagal tone during synchronous or asynchronous slideshows.

Discussion

Limitations

The limitations of this study are inadequate power for visual behavior analysis because of small sample size, decreased
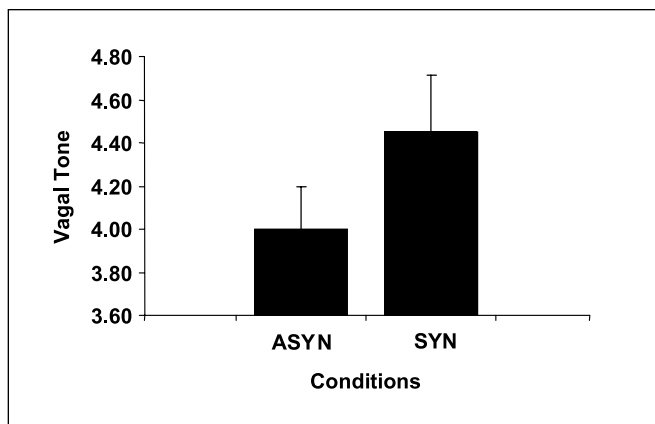
Figure 2. Changes in heart rate variability across conditions.
Note. ASYN = asynchronous; SYN = synchronous.

generalizability, and use of a new paradigm to study the effects of temporal synchrony on visual behavior and physiology. Additional measures of physiology such as skin conductance may indicate whether temporal asynchrony activates the sympathetic nervous system and whether asynchronous auditory and visual stimuli are mildly stressful for infants.

Power Analysis and Effect Size

The use of a repeated-measures design to investigate how infants perceive redundant sensory stimuli is new. Research paradigms routinely used in the field of intersensory perception include testing infants by presenting them with competing stimuli or exposing them to novel and familiar objects while monitoring visual recovery. The repeated-measures design used in this study allowed for the collection of physiological and behavioral data concurrently while isolating the conditions of temporal synchrony and asynchrony. Because the findings indicate that infants' visual behavior was not different during the asynchronous and synchronous conditions, power analysis was used to assist in the interpretation process.

Power analysis serves two purposes: (1) to estimate sample size when designing a study and (2) to interpret the results of an experiment when the findings indicate no significant effects or differences between treatments (Portney & Watkins, 2000). As mentioned earlier, the finding that infants looked equivalently at the synchronous and asynchronous slideshows was unexpected. Previous studies examining visual behavior suggested that infants detect differences between synchronous and asynchronous events as demonstrated by differences in looking behavior (Lewkowicz, 2000) and that redundant information is highly salient in infancy (Bahrick & Lickliter, 2000).

The use of repeated-measures research design needs to be considered to reconcile the previous reports of increased visual attention during presentations of synchronous stimuli.

Various paradigms yield different types of responses, and infants may be processing the stimuli in a dissimilar fashion depending on the methods used (Lewkowicz, 2000). In the present study, infants were not habituated to a particular event, nor were they presented with competing stimuli as they would be in paired preference procedures. The infants viewed either a synchronous or an asynchronous condition (repeated measures), and at age 3 months their visual motor system responded equivalently across the conditions. It appears that, when using a repeated-measures paradigm, differential looking responses during asynchronous and synchronous conditions may not be noted. Power analysis indicated that to see an effect of condition (asynchronous vs. synchronous) when examining visual behavior, a sample size of more than 100 observations would be needed. The small sample size may be one reason that an effect was not seen.

The second finding, that the infants' autonomic nervous system responses were different for temporally synchronous and asynchronous stimuli, indicates that at a physiological level, the infants appear to detect differences. Given a sample size of 13, the magnitude of the difference (effect size) between the synchronous and asynchronous conditions was .478. This calculated effect size indicates a medium or moderate effect (Cohen, 1973).

Infant Physiology and Looking Behavior

It was interesting that this detection was reflected not in looking behaviors but in changes in physiology. The slideshow order was counterbalanced to ensure that relative increases or decreases in vagal tone response to synchronous or asynchronous visual stimuli could not be attributed to time or the preceding maternal–infant interactive session. The findings suggest that physiological responses to the stimuli may be attributed to the characteristics of the stimuli and not to when the infants viewed the stimuli or what happened before they viewed the stimuli.

Although the current finding of decreases in vagal tone during temporal asynchrony is not consistent with the original hypothesis, increases in vagal tone during sustained attention have been found more recently. Bozhenova, Plonskaia, and Porges (2001) found increased vagal tone during sustained attention and engagement during object presentation in 5-month-old infants. Increased vagal tone was attributed to the complexity of the attention system. That is, attention requires coordination of visual orienting, search, attention processing, and memory, in addition to coordination of emotional systems. At 5 months, infants are able to demonstrate autonomic nervous system mediation of the behavioral response (Bozhenova et al., 2001). It is possible that at 3.5 months, the autonomic nervous system is not yet capable of mediating the visual response.

In keeping with Bozhenova et al.'s (2001) view of the complex attention system, the visual responses shown by the infants in this study were primarily reactive in nature. The infants typically looked for less than 5 sec and averaged 3 to 4 sustained looks during a 2-min period. Richards (1985) found that infants between ages 14 weeks and 26 weeks engaged in progressively increasing amounts of sustained attention and that measures of vagal tone indexed sustained attention, not reactive attention, in the older infants. Therefore, the infants' reactive looking and their respective developmental ages may have contributed to a lack of association between vagal tone and looking as originally hypothesized. Results from this study generally suggest that, even in the absence of visual responses, redundant information is processed, and physiological responses are notable in infancy. Vagal tone responses may be precursors to visual behavior in the discrimination of temporal synchrony and asynchrony.

Implications for Occupational Therapy

Given the nature of this pilot project, bridging the gap between basic science research and the richness of occupation seems to be a formidable challenge. The performance and engagement in occupation is directly related to underlying capacities and abilities (American Occupational Therapy Association, 2002). Newborns have unique capabilities in processing temporal information through sensory and physiological systems (Bahrick & Lickliter, 2000; Lewkowicz, 2000; Spelke, 1976). The unique abilities to perceive temporally synchronous events may be directly related to an infant's ability to engage in the occupation of play with toys or objects. Infants are quite adept at detecting object attributes related to temporality using their visual and auditory systems, and this ability may provide a foundational component for understanding other object attributes (rate, pitch, duration, frequency) found in their environment (Lewkowicz, 2000).

Findings from this pilot study suggest that, even though infants may not outwardly show signs of increased visual attention, they may be experiencing physiological responses to the stimuli present during object play. A decoupling of the behavioral and physiological systems suggests that engagement in the occupation of object play is complex and involves multiple systems. A greater understanding of the multifaceted nature of perception during object play may facilitate greater understanding of how and why infants engage in certain aspects of playful occupations. For example, infants may be more attracted to toys that reflect light or flash light congruently with a sound. These toys could be recommended to parents who are seeking information about developmentally appropriate toys for their infants.

Moreover, occupational therapy scholars interested in infant perception may offer a unique understanding of how infants and children with disabilities are able to tolerate, detect, and respond to redundant stimuli. Do toddlers with a diagnosis such as autism respond behaviorally and physiologically to temporal characteristics of objects in the same manner as those who are typically developing? Intuitively, it seems that processing redundant sensory stimuli for children with autism or pervasive developmental disorders may be difficult. It may be that infants with disabilities have a decreased tolerance to redundant information and subsequently do not develop the perceptual skills needed to support play. Future studies could examine whether differences in physiological responses during presentation of sensory redundant stimuli is a marker or predictor of sensory processing dysfunction. ▲
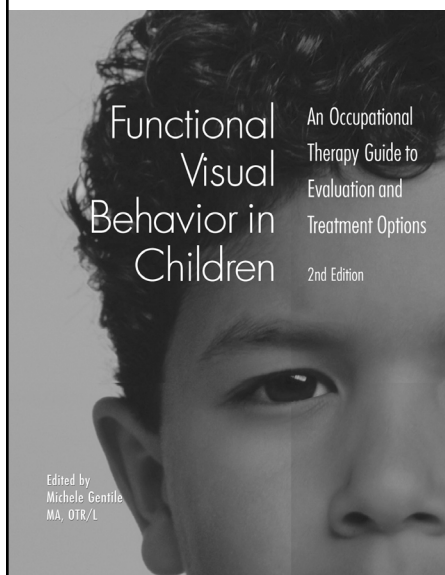
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