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Infant Gaze Direction, Early Vocalizations, and Vocabulary Development

by

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Sincerely,

Ralph Baergen, PhD, MPH, CIP
Human Subjects Chair

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Infant Gaze Direction, Early Vocalizations, and Vocabulary Development

Thesis Abstract—Idaho State University (2018)

The purpose of this project was to determine if there was a relationship between gaze direction and later development of expressive and receptive vocabulary. We hypothesized that there would be a relationship between gaze (before, during, and after infant vocalization) and later vocabulary development. Data was extracted from a longitudinal study comparing gaze direction in 15 infants at 8, 10, 12, 14, and 16 months of age and how that related to expressive and receptive vocabulary development in the same children at 1.5, 2, and 3 years of age. Gaze direction was coded with an observer-based classification system, while vocabulary was documented through standardized parent report. The results indicated a clinically relevant relationship between 8, 10, 12, 14, and 16-month-old infants' gaze direction before, during, and after spontaneous vocalizations and their later expressive and receptive vocabulary development from 1.5 to 3 years. If studied further, these results could be used in establishing additional factors that impact later development, therefore aiding in early identification and intervention. Strategies to facilitate vocabulary development through early gaze direction could also be established in future work. Clinical implications, study limitations, and future directions will be discussed.

Key Words: infant, toddler, prelinguistic, vocabulary, communication, development, eye gaze, early, vocalization, language

Infant Gaze Direction, Early Vocalization, and Vocabulary Development

Introduction

Vocabulary growth is crucial for a child's language development. It is the foundation for later language needed in school. A well-developed vocabulary is necessary for literacy comprehension and communication as a whole (Moghadam, Zainal, & Ghaderpour, 2012). Similarly, some argue that vocabulary growth can be used to predict school-aged reading comprehension (Duff, Reen, Plunkett, & Nation, 2015). If a child has a low vocabulary, he or she is at a higher risk for later language difficulty. The rate of growth and size of vocabulary varies for toddlers (Cartmill et al., 2013; Mayor & Plunkett 2011; Rowe, Özçalişkan, & Goldin-Meadow, 2008). According to normative data, children in the 10th percentile for vocabulary have developed an average of 560.2 words by 30 months of age, while children in the 90th percentile display a drastically larger vocabulary of 2032.9 words by 30 months (Mayor & Plunkett, 2011). However, before a child develops this measurable vocabulary and creates meaningful first words, he or she learns to communicate through prelinguistic behaviors (Määttä, Laakso, Tolvanen, Westerholm, & Aro, 2016).

Many prelinguistic skills, as well as other aspects of an infant's development, are responsible for variability in vocabulary development and can be indicators of vocabulary size in childhood, including: parental interaction, gender, mobility during the first year of life, and non-verbal communication (Mayor & Plunkett, 2011; Rowe et al., 2008). Infants who do not acquire, or are delayed in developing these skills lack important characteristics of typical language development. For speech-language pathologists (SLPs), increasing the evidence-based knowledge available regarding factors that contribute to vocabulary size, such as prelinguistic communication, could lead to earlier identification of language delay/disorder as well as more comprehensive early intervention approaches.

Prelinguistic Communication

Watt, Wetherby, and Shumway (2006) define prelinguistic communication as an infant's transition into first words, using mainly preverbal acts for communication. This would include gestures, joint attention, play, early vocalization, and even first words. Prelinguistic behaviors are carried out by the infant for communicative and social purposes. Research has shown the importance of prelinguistic communication and the ability to use it as a factor in predicting later language outcomes. Some argue that prelinguistic skills, such as pointing, set the framework for communication (Goldin-Meadow, 2007). As prelinguistic skills develop, early social communication skills in infants, such as joint attention, are more readily carried out and provide children with the building blocks necessary for later language learning and development.

Humans are driven by the need and desire to share attention with others. Similarly, infants anticipate positive reactions from others in regard to themselves and their actions (Liszkowski, Carpenter, Henning, Striano, & Tomasello, 2004). Thorup, Nyström, Gredebäck, Bölte, and Falck-Ytter (2016) depict a scenario of an infant and her father. The father makes eye contact with his baby girl and then looks directly at a toy sitting in front of them. In reaction to her father's change in gaze, the baby too looks at the toy. This interaction establishes joint attention, which is the ability of both communication partners to focus on the same object. Before an infant initiates joint attention, the adult communication partner takes the lead in establishing this act. The scaffolding given by the partner in this early stage of joint attention will teach the infant that eye gaze is a social cue given by a communication partner that indicates what the partner is thinking about. Eye gaze and other social cues, such as pointing, are important for the establishment of joint attention and general language abilities. In one study, it was suggested that language development could be facilitated by social engagement (Tenenbaum, Sobel, Sheinkopf, Malle, & Morgan, 2015). The social engagement of communication is what pushes a child to attend to the mouth of the speaker, as well as follow the speaker's gaze direction, both of which facilitate joint attention. Joint attention is considered a prelinguistic act in and of itself, but also requires a variety of other prelinguistic acts from the infant, as well as various types of responses or acts from his or her caregiver. Though many prelinguistic acts are used to implement and maintain joint attention, gaze-following (as seen through the previous example of the father and his daughter) is arguably the most prominent.

Following Eye-Gaze

One fundamental prelinguistic skill necessary for joint attention, and later communication, is the following of social cues, such as following an eye-gaze. Though some have thought that infants follow head turn rather than gaze, Brooks and Meltzolf (2005) discovered that this is not always true. Their study included three groups (9, 10, and 11 months); each group consisted of 32 infants. Each infant was placed in front of two objects. The examiner stood behind the objects and looked at the target object with either opened or closed eyes; this was done four times. The trials were recorded and examined by a coder who scored the infants' gaze and vocalizations. Results were then analyzed using an analysis of variance, as well as chi-squares. The results indicated that at 9 months, infants are not aware of opened or closed eyes and do indeed follow head turn rather than gaze. However, by 10 months, they follow eye-gaze rather than head turn. After all experimental trials were complete, a comprehensive vocabulary test was given to a group of the 10 to 11-month-old infants. Results supported previous findings that eye-gaze aids in the acquisition of language. Though the study did show significant correlation between eye-gaze and vocabulary comprehension, no such correlation was found for eye-gaze and vocabulary production. However, this could be due to the infants' age at the time of the vocabulary test or other factors that play into expressive language such as the infants' speech sound production. In contrast, Tenenbaum and colleagues (2015) found that attention to the mouth and attention to gaze were not significant indicators of receptive vocabulary, but were significant predictors of expressive vocabulary at both 18 and 24 months. The findings of these studies may seem contradictory, but they both lead to the conclusion that eye-gaze can predict different aspects of language and, more specifically, vocabulary development.

In studies involving eye-gaze, the use of eye-tracking technology has become increasingly popular, especially among infant researchers (Corbetta, Guan, & Williams, 2012). However, like all technology, there are advantages, as well as disadvantages with these products. For example, Corbetta and colleagues (2012) set out to test two methods of measuring infant eye-gaze, both of which involved eye-tracking technology, and discussed the advantages and disadvantages of each. The two methods used in the experiment were head-mounted technology and remote eye-trackers. Though they found both beneficial and accurate in assessing gaze, they identified a couple of disadvantages with each method. Using head-mounted technology is problematic with infants because it is difficult to keep the device in place and stable on their heads. This is not an issue with remote eye-tracking. However, remote eye-tracking presented as problematic when the infant turned away from the tracking device, causing data to be lost due to the tracking device not being able to locate a pupil. This issue would not have a significant impact on more controlled studies, but could be detrimental in more naturalistic settings where the infant is frequently moving. The mentioned study only looked at two types of eye-tracking technologies. However, other technologies and techniques involving eye-tracking devices have become available to the research community, such as glass, table-mounted, and embedded systems (Fu, Wei, Camastra, Arico, & Sheng, 2016). With increased technology, eye-tracking devices are more frequently being used in studies involving infant gaze. However, this equipment is expensive and time consuming to calibrate, making clinical application difficult.

Paul and Fikkert (2014) used eye-tracking technology to look at the development of social cue reliance, and which cue (pointing or gazing) infants preferred when learning vocabulary. The study involved 12 adults and 32 infants, half who were 14-months-old and half who were 24-months-old. Each participant was presented with stimuli on a television screen and his or her eye movement was assessed using eye-tracking technology. The stimuli presented consisted of two objects and a model who stood in the middle of the two objects. The model looked at one object and pointed to the other while verbalizing a nonsense word for labeling. The participants' eye movements were measured to track if they focused on the object being pointed to or the object receiving the model's gaze. When the results were compared, findings indicated that the 14-month-old infants relied more on eye-gaze cue, whereas the 24-month-old infants and adults relied more on pointing cues to learn new words. This verified the researchers' hypothesis that there are developmental differences in the reliance of social cues and that the importance of certain social cues changes overtime. This is an important aspect to remember when assessing prelinguistic skills in infants. However, infants not only rely on social cues from communication partners, but also use certain cues themselves, such as pointing, to communicate.

Infant initiated social cues, such as pointing acts, can set the framework for communication (Goldin-Meadow, 2007). Adults can use pointing as a way to identify a referent and establish joint attention. Similarly, infant pointing prompts the caregiver to produce the type of vocabulary the infant needs to hear in order to aid development (Goldin-Meadow, 2007).

Pointing allows the caregiver to know where the infant's attention is and what to reference when talking. In turn, this referential talking aids the child's understanding of the referent. Brooks and Meltzoff (2008) discovered that, not only did pointing aid vocabulary growth, but vocabulary growth was also increased when an infant used both the gesture of pointing and looked at the referent for an extended period of time. Overall, pointing can be a factor in predicting vocabulary growth, but other prelinguistic factors combined with pointing can also lead to a greater understanding of a child's language.

Prelinguistic Combinations

Though pointing and gaze-following can both independently predict vocabulary, using them together increases predictability (Brooks & Meltzoff, 2008). Brooks and Meltzoff (2008) discovered this through a study of eye-gaze and pointing in relation to vocabulary growth. The longitudinal study examined 32 infants ages 10 to 11 months to 2 years. The infants' eye-gaze, pointing, and vocabulary were all assessed at certain target ages (10/11 months, 1;2 years, 1;6 years, and 2 years). For each target age, the participant's parent filled out the *MacArthur-Bates Communicative Developmental Inventories (CDI)* before the session. During the session, two objects were placed in front of the child. The examiner looked at one of the objects and the child's response was recorded and analyzed by another examiner who was unaware of the child's *CDI* score and the gaze direction of the first examiner. The child's gaze was scored for correct looks, incorrect looks, frequency of looking, and the child was given a general pointing score as well. The results were analyzed and indicated that the infants in the study displayed significant gaze following, looked more often at the correct stimulus than the incorrect stimulus, and that their pointing score positively correlated to vocabulary outcomes. Conversely, the results indicated that poor eye-gaze was related to lower vocabulary growth. This indicates that poor eye-gaze by an infant may be cause for concern. Overall, the researchers found that both eye-gaze and pointing were predictors of vocabulary growth, and concluded that the combination of infant eye-gaze and pointing is the best predictor.

Other prelinguistic factors have also been shown to be effective in predicting infant vocabulary growth when integrated together. One such combination is the use of gaze following with spontaneous vocalization; when these two factors are produced together, later vocabulary comprehension can be predicted (Brooks & Meltzoff, 2005). Similarly, another reliable combination used to predict later language outcomes is prelinguistic vocalization and pointing. Researchers discovered that when infants used this combination, there was an increase in vocabulary comprehension as a result of gaining the mother's attention (Wu & Gros-Louis, 2014). Infants communicating in this way may be demonstrating a readiness to learn.

Readiness to Learn and Early Vocalizations

Infant vocalizations that are prelinguistic in nature and gestures such as pointing have been revealed to indicate the infant's readiness to learn when those vocalizations are directed at an object (Goldin-Meadow, 2007; Goldstein, Schwade, Briesch, & Syal, 2010). Prelinguistic vocalizations known as Object Directed Vocalizations (ODVs) are defined as "a noncry prelinguistic vocalization uttered when the infant is looking at an object that is within reach or is being held" (Goldstein et al., 2010, p. 364). For example, ODVs could occur when a mother is playing with her child and then the child makes a vocalization towards a toy the mother is holding. Through two experiments, Goldstein and colleagues (2010) set out to discover how ODVs relate to a child's language development.

Experiment 1 focused on the role of ODVs relative to infant attention. Each of the fourteen 12-month-old infants participated in one session which consisted of three phases, the first being a warm-up. This phase involved interaction between the infant, parent, and experimenter. This allowed the infant to get comfortable with the facility so that he or she would vocalize more during the other phases. The infant was then brought into a different room for the object exploration phase. In this phase, the infant was presented with 12 objects in a random order. The infant had 40 seconds with each object. While the infant played with each object, ODVs were being counted in the control room. The objects receiving the highest number and the lowest number of ODVs were then determined for use in the testing phase. In this phase the two previously determined objects were presented on the screen along with a shape-distorted, matched object of each to determine the infant's ability to learn object features. The session was recorded and then coded at a later time for infant looking, handling, and the duration of looking and handling. Through this first experiment, they discovered that infants learned the properties of the objects to which they vocalized, but the amount of vocalization to the object did not seem to be a contributor to this learning.

Within the same study, Goldstein and colleagues (2010) carried out a second experiment which focused on infant babbling as it relates to learning associations between objects and words. This study consisted of 40 infants between the ages of 10 and 12 months. Participants were split into two groups, one having a focus on ODVs and the other on silent looks (SL). Infant object exploration and vocalizations were tested in the same manner as in experiment 1, through three phases, with the warm-up phase being the same. However, for experiment 2, the object training phase consisted of the presentation of two novel objects, one being the target and the other a distracter. The target object was labeled with infant directed speech using a novel name as the label for the object. The distracter label followed the same pattern, but was labeled "that" rather than given a novel name. The ODV group received a label for each ODV produced, while the SL group received labels when the infant was looking at the object without vocalization. The session ended with the test phase. Two objects were presented on a screen and the infant was given the phrase, “Look at the (object label). Can you find it?” A camera recorded the infant’s gaze to determine the object to which the infant focused. All sessions were recorded and later coded for infant gaze, vocalizations, object handling, and the duration of looking and handling. Through experiment 2, they discovered that labeling an object based upon the ODVs aided the infant in learning the association between words and objects. Overall, a combination of the results indicated that ODVs are representative of focused attention, indicating a readiness to learn. This knowledge is significant in understanding an infant’s zone of proximal development in relation to vocabulary development. However, ODVs are only one aspect of an infant’s readiness to learn.

Pointing indicates a readiness to learn as well. As a child matures, pointing gestures are acquired and, according to Gros-Louis, West, and King (2014), infant gestures help to facilitate communication with caregivers. They also argue that prelinguistic vocalizations, when directed to objects or people, can be used in a similar fashion by the infant to indicate to the caregiver to what he or she is attending. Similarly, others, such as Liszkowski and colleagues (2004), argue that infants begin to point in order to communicate and share attention with other people. They suggest that infants develop an understanding that their communication partner should attend to the same object the infant does and that the partner should make a comment about the shared object. When children begin to display an understanding of these two concepts, it demonstrates they are ready to learn. This understanding is revealed through the initiation of joint attention and anticipation of a caregiver’s response. The caregiver, such as the mother, can then respond in such a way as to aid and boost communicative input to the child and aid the child’s language learning. For example, an infant boy looks at a cat and then points to the cat. When his mother sees this, she acknowledges the pointing cue and understands the referent the child is questioning. In response to this, she might label the object her son is pointing to as a cat, fulfilling her son's social questioning and scaffolding his vocabulary growth. This maternal response to the infant's prelinguistic behavior is necessary for the vocabulary and language development of the child.

Parental Responsiveness

Prelinguistic acts are increasingly beneficial when paired with positive parental responsiveness. Many prelinguistic acts, such as vocalizing and pointing, are used to gain the mother's attention, and have been shown to increase vocabulary comprehension (Wu & Gros-Louis, 2014). Knowing the infant is ready to learn through his or her prelinguistic acts allows caregivers to respond in appropriate ways to continually boost the child's development. Vocabulary outcomes can be predicted based upon the mother's labeling response to the infant's gestures of curiosity (Olson & Masur, 2015). Gros-Louis and colleagues (2014) conducted a study involving 12 infants and their mothers. Each mother and infant dyad began the study within 1 week after the infant's 8-month birthday and continued participation for 6 months, visiting the laboratory every other week. During each of the 12 sessions, the mother interacted with the infant similarly to the way she would at home, which aided in the attempt to create a natural environment. Sessions were recorded and then coded for infant vocalizations, maternal contingent responses, and maternal verbal responses. By comparing infant vocalizations and maternal responsiveness, it was discovered that maternal contingent responses predicted a developmental change in the use of vocalizations by the infant. This finding supports that the mother's response scaffolds the child in social interaction, which can be used as a tool in the development of communicative milestones.

In accordance with the finding mentioned above, it can be argued that a mother's response to prelinguistic vocalizations aids in her child's pragmatic development. These pragmatic interactions during the developmental stage of prelinguistic communication enable the child's semantics to grow by increasing word learning. Maternal responsiveness is an important key to a child's development in both pragmatic and semantic domains. Her response to the child's prelinguistic acts teaches the child that there is meaning to his or her vocalizations (Gros-Louis et al., 2014).

Goldstein and Schwade (2010) also discovered that when social partners interact with infants and assign meaning to their prelinguistic behaviors, infants will begin to produce more advanced vocalizations. They compared this phenomenon with that of songbirds. In their study, they explain that songbirds can develop more mature and advanced song forms and vocalizations through the acts of their social partner. Similarly, this social influence is also seen when caregivers respond to prelinguistic vocalization; the infant's vocalizations become more advanced through this social process and they learn how to form syllables as well as how to string these syllables together. The mother's response in shaping these vocalizations is key in transitioning the child from prelinguistic communication to intentional verbal communication, setting the stage for first words and utterances.

Purpose of Current Study

Whether it is through a parent's response or through the act of the child, it is known that prelinguistic behaviors, such as pointing and gaze-following, are predictor variables for later language development (Brooks & Meltzoff, 2008). Current research has focused on infant gaze-following when caregivers vocalize (Tenenbaum, Sobel, Sheinkopf, Malle, & Morgan, 2015). However, little is known about how infant gaze before, during, and after his or her own vocalizations affects later language development. Though it has been shown that ODVs may indicate an infant's readiness to learn, researchers still question the relationship of vocalization and focused attention (Goldstein, Schwade, Briesch, & Syal, 2010). In addition, previous studies involving infant gaze have used advanced eye tracking equipment to identify focus of attention (Paulus & Fikkert, 2014), but this equipment is expensive, making clinical application difficult.

The long-term goal of the current study was to establish prelinguistic behaviors, such as gaze directionality, that are linked with later speech and language development, to inform clinical practice and early identification of children at risk. In the present project, gaze directionality was observed, analyzed, and identified using methods that were practical (e.g., cost effective and time efficient) and could be easily implemented as identifiers in clinical practice. The objective of this project was to identify the relationship between gaze direction and later development of expressive and receptive vocabulary. We accomplished this through a longitudinal study of gaze direction in 15 infants at 8, 10, 12, 14, and 16 months of age and how that relates to expressive and receptive vocabulary development at 1.5, 2, and 3 years of age in the same children. The central hypothesis was that there would be a relationship between the infants' gaze direction before, during, and after spontaneous vocalizations and their later expressive and receptive vocabulary development. The hypothesis was formulated from previous research showing a relationship between the general growth of prelinguistic behaviors and later language development (Määttä, Laakso, Tolvanen, Westerholm, & Aro, 2016). The rationale for this study was that if eye gaze is related to later vocabulary, treatment methods could be developed to promote early intervention of such behaviors with infants who are at risk for a language delay or disorder. In addition, using an observer-based classification system to identify these early risks would allow a greater number of clinicians to practically implement this research into practice.

Methods

Data for this project was obtained from a longitudinal study conducted by Dr. Heather Ramsdell-Hudock at East Carolina University (ECU). This study was approved by the University and Medical Center Institutional Review Board at ECU prior to initial testing of participants and voluntary consent was given by all caregivers.

Participants

Research advertisements were sent to homes that contained infants born between November, 2010 and March, 2011. Interested families were interviewed, details of the study were discussed, and consent was given by the caregivers. Fifteen parent/infant dyads from 6 to 18 months of age participated in the study, which included six males and nine females. There were originally 16 dyads; however, one infant was excluded for atypical development. All families received $98 in gift cards every 2 months of participation in the study. The study had the following inclusion criteria: caregivers must have had a normal pregnancy with no significant history of prenatal or perinatal problems; the infants were not at risk for language development disorder, came from middle socioeconomic status, had normal hearing, and English was the primary language spoken in the home.

Of the 15 infant participants, one female was African American and one male was Asian American. In addition, one male came from a home where three languages were spoken and one male came from a home where two different languages were spoken. However, in both homes, English was listed as one of the primary languages. To ensure hearing was within normal limits, hearing evaluations were administered at 6 and 18 months of age. Each evaluation consisted of tympanometry, transient evoked otoacoustic emissions, and visual reinforcement audiometry. If abnormal or incomplete results occurred, a follow-up evaluation was performed. Two infants underwent a bilateral myringotomy and had pressure equalization tubes placed while participating in the study.

Materials and Procedures

Laboratory setting. Participants came to the research lab once a month for an hour session and were recorded for later data collection. The room was equipped with eight Sony EVI-D70/W cameras which were mounted on the wall of the lab. Additionally, audio from the session was recorded for infants using a wireless microphone housed in a vest, and for caregivers using a wireless lapel microphone. During each session, all recordings were transmitted to an adjacent control room where laboratory staff chose two cameras angles to capture. Staff chose the best view of the infant's face and the best view of the caregiver interaction. In an attempt to capture a natural interaction, the lab was set up as similarly as possible to a typical infant's room/ nursery and the parents were told to interact with their child as they would at home.

Consensus coding. All coders were trained laboratory staff in the Infant Vocal Development Laboratory at Idaho State University under the direction of Dr. Heather L. Ramsdell-Hudock. The coders worked with infant utterance location and/or gaze direction coding. For location of infant utterances and coding of gaze direction during those utterances, there were 22 coders involved; 18 coders participated in utterance location and 14 participated in gaze direction coding (with some coders involved in both tasks). The current study utilized infant utterances from 202 twenty-minute sessions. Infant utterance types were assigned as follows: two or more of the 18 coders located infant utterances in 167 sessions (not always the same two coders; 82.7% of the total sessions), and in 35 sessions a single coder located utterances (17.1% of the total sessions). In instances where only a single coder located utterances, the coder was a senior coder in the Infant Vocal Development Laboratory, having worked with infant/caregiver data for approximately 20 hours per week for at least 2 years. Gaze direction codes, for gaze during utterances, were assigned as follows: one of the coders (not always the same coder) coded each of the sessions for gaze direction, and a different coder checked the codes for accuracy and consensus. Each gaze direction code was determined to be accurate by at least two laboratory staff. For the present study, additional coding of gaze direction before and after utterances was completed in a similar fashion. However, for these codes, 8 coders were involved. Each coder worked independently, but cross-checked questionable codes with another coder.

Infant utterances. Infant utterance location and coding of audio/video recordings were conducted within a software environment (Action Analysis Coding and Training software, AACT) that coordinates frame accurate video and audio presentation with real-time acoustic displays in TF32 (AACT, 1996). Utterance location boundaries were used to determine video playback (via Windows Media Player) for gaze direction coding in the present study, also using AACT. Infant utterances were located using a breath-group criterion, determined by the direction of airflow; each vocalization occurred on a single egressive breath (Oller & Lynch, 1992). Vegetative and reflexive sounds, and vocalizations with significant vocal or noise (e.g., toy) overlay were not included.

Gaze direction. Once infant utterances were located, they were coded for gaze direction as either *Directed to Person, Directed to Object, Not-Directed,* or *Cannot See.* The coding was conducted with the sound off, as no auditory support was allowed (so that utterance quality and type did not skew coder judgment). *Directed to Person* was coded when the baby was looking in the direction of an adult or sibling in the room at any time during a vocalization. This included vocalizations produced while looking at themselves or another individual in a wall mirror. Looking at themselves in a wall mirror was coded as *Directed to Person* because the majority of infants do not develop a recognition of self until around 24 months of age and all vocalizations were produced at 18 months of age or younger (Anderson, 1984). Eye contact was a sure indicator for the *Directed to Person* code, but looking at the body of a communication partner could have also been used as an indicator at the coder's discretion. *Directed to Object* was coded when the baby was looking in the direction of any object in the room (e.g., toy, water bottle, camera) at any time during a vocalization. *Not-Directed* was coded when the infant was looking into space, at the floor, at the wall, at furniture, or at the edge of a wall mirror; the infant could not be looking at another person in the room, object in the room, or in the mirror at any time during a *Not-Directed* vocalization. *Cannot See* was coded when the infant's gaze direction could not be determined, particularly when the baby's eyes or head orientation were not clear. In these instances, the camera was typically not on the infant at all, given delayed camera movement as a result of quick infant movement, for example. Gaze direction was then similarly coded for the time directly preceding (and adjacent to), and then following (and adjacent to) infant vocalizations. If the infant changed gaze within a "before" or "after" boundary (i.e. when the infant looked at a person and an object within the same boundary window), gaze code was determined by where the infant was looking for the majority of the time.

Vocabulary. Parent report has been recognized as both a reliable and valid means of determining speech language development in infants and toddlers (Feldman *et al.*, 2005; Fenson *et al.*, 1994; Heilmann, Ellis Weismer, Evans, & Hollar, 2005; Korkman, Jaakkola, Ahlroth, Pesonen, & Turunen, 2004; Oller, Eilers, & Bassinger, 2001; Rescorla & Alley, 2001).

The MacArthur-Bates Communicative Development Inventory (CDI) was the parent report measure of vocabulary for the present study (Fenson et al., 1991). The CDI has several studies to support its concurrent and predictive validity as a measure of vocabulary (Feldman *et al.*, 2005; Heilmann *et. al.,* 2005). In a study by Feldman and colleagues in 2005, the CDI was shown to have positive and statistically significant concurrent validity when compared to three standardized accepted measures of infant language and cognition (e.g., *McCarthy General Cognitive Index*, the *McCarthy Verbal Scale*, and the *Peabody Picture Vocabulary Test-Revised*) and when compared to number of different words and mean length of utterance determined by recording parent to child conversations. A study by Heilmann and colleagues (2005) found the CDI to be positively correlated with the *Preschool Language Scales* III, the number of different words produced by the child according to the *Systematic Language Transcription Analysis* (SALT), and the child's mean length of utterance. Results of these studies indicate that the CDI is a valid measure of vocabulary and expressive language in toddlers.

Caregivers completed the CDI *Words and Gestures* bi-monthly from 10 to 18 months of infant age, and *Words and Sentences* in follow-up studies at 2 and 3 years of age. From the inventories, the number of words produced by infants were tallied at three points in time (ranges presented because the individual infants varied in age at each point in time): one and a half years (15 to 18 months), two years (23 to 27 months), and three years (37 to 40 months) of infant age for expressive language. For the current study, the CDI was used as a measure of expressive vocabulary at 1.5, 2, and 3 years of age, and receptive vocabulary at 1.5 years of age. The *Words and Sentences* subtest used in follow-up studies did not include a measure of receptive vocabulary. Therefore, receptive vocabulary was not analyzed at 2 and 3 years of age.

Design

Correlation and multiple regression analyses were conducted to examine the relationship between all criterion and predictor variables. Variables of interest are presented in *Figure 1.* The criterion variables of interest were expressive and receptive vocabulary at 1 ½ years of age, and expressive vocabulary at 2 and 3 years of age. The predictor variables of interest were gaze direction (*Directed to Person, Directed to Object* and *Not-Directed*) prior to, during, and after vocalizations, and infant age at 8, 10, 12, 14, and 16 months.

Results

The 15 participants produced a total of 7,101 utterances in the middle 20 minutes of 60 minute recordings at 8, 10, 12, 14, and 16 months of age. Further, the raw number of predictor variables (gaze direction to person, object, and nothing prior to, during and after vocations across 8, 10, 12, 14, and 16 months of age) are shown in Table 1. The number of utterances produced, while variable, increased with infant age, both within and across ages. Regardless of gaze location with respect to utterances, the majority of gazes were directed to an object, followed by directed to a person, and finally not directed. Table 2 shows the vocabulary scores of each infant as indicated on the CDI. Results show an increase in vocabulary with an increase in infant age, which follows typical developmental patterns.

Expressive Vocabulary at 1 ½ Years

Table 3 summarizes the descriptive statistics and analysis results when examining the relationship between expressive vocabulary at 1 ½ years with all potential predictor variables. As can be seen, expressive vocabulary at 1 ½ years of age was not significantly correlated with any of the predictor variables.

The multiple regression model with all predictors at 8 months of age before utterances produced an $R^2 = 0.169$, $F(3, 14) = 0.900$, $p = 0.472$, during utterances produced an $R^2 = 0.204$, $F(3, 14) = 0.942$, $p = 0.453$, and after utterances produced an $R^2 = 0.178$, $F(3, 14) = 0.794$, $p = 0.522$; at 10 months of age, before utterances produced an $R^2 = 0.007$, $F(3, 14) = 0.026$, $p = 0.994$, during utterances produced an $R^2 = 0.004$, $F(3, 14) = 0.013$, $p = 0.998$, and after utterances produced an $R^2 = 0.008$, $F(3, 14) = 0.030$, $p = 0.992$; at 12 months of age, before utterances produced an $R^2 = 0.255$, $F(3, 14) = 1.255$, $p = 0.337$, during utterances produced an $R^2 = 0.193$, $F(3, 14) = 0.876$, $p = 0.483$, and after utterances produced an $R^2 = 0.351$, $F(3, 14) = 1.979$, $p = 0.176$; at 14 months of age, before utterances produced an $R^2 = 0.119$, $F(3, 14) = 0.494$, $p = 0.694$, during utterances produced an $R^2 = 0.176$, $F(3, 14) = 0.784$, $p = 0.528$, and after utterances produced an $R^2 = 0.230$, $F(3, 14) = 1.096$, $p = 0.392$; and at 16 months of age, before utterances produced an $R^2 = 0.155$, $F(3, 14) = 0.672$, $p = 0.587$, during utterances produced an $R^2 = 0.106$, $F(3, 14) = 0.433$, $p = 0.734$, and after utterances produced an $R^2 = 0.122$, $F(3, 14) = 0.512$, $p = 0.682$.

Gaze direction (*Directed to Person, Directed to Object* and *Not-Directed*) prior to, during, and after vocalizations, and infant age at 8, 10, 12, 14, and 16 months did not significantly contribute to the multiple regression model for expressive vocabulary at 1 ½ years.

Receptive Vocabulary at 1 ½ Years

Table 4 summarizes the descriptive statistics and analysis results when examining the relationship between receptive vocabulary at 1 ½ years with all potential predictor variables. As can be seen, receptive vocabulary at 1 ½ years of age was not significantly correlated with any of the predictor variables.

The multiple regression model with all predictors at 8 months of age before utterances produced an $R^2 = 0.206$, $F(3, 14) = 0.953$, $p = 0.449$, during utterances produced an $R^2 = 0.168$, $F(3, 14) = 0.739$, $p = 0.550$, and after utterances produced an $R^2 = 0.241$, $F(3, 14) = 1.162$, $p = 0.368$; at 10 months of age, before utterances produced an $R^2 = 0.117$, $F(3, 14) = 0.487$, $p = 0.698$, during utterances produced an $R^2 = 0.107$, $F(3, 14) = 0.441$, $p = 0.729$, and after utterances produced an $R^2 = 0.112$, $F(3, 14) = 0.461$, $p = 0.715$; at 12 months of age, before utterances produced an $R^2 = 0.138$, $F(3, 14) = 0.585$, $p = 0.637$, during utterances produced an $R^2 = 0.179$, $F(3, 14) = 0.799$, $p = 0.520$, and after utterances produced an $R^2 = 0.226$, $F(3, 14) = 1.068$, $p = 0.402$; at 14 months of age, before utterances produced an $R^2 = 0.024$, $F(3, 14) = 0.092$, $p = 0.963$, during utterances produced an $R^2 = 0.049$, $F(3, 14) = 0.190$, $p = 0.901$, and after utterances produced an $R^2 = 0.049$, $F(3, 14) = 0.189$, $p = 0.902$; and at 16 months of age, before utterances produced an $R^2 = 0.157$, $F(3, 14) = 0.685$, $p = 0.580$, during utterances produced an $R^2 = 0.196$, $F(3, 14) = 0.896$, $p = 0.474$, and after utterances produced an $R^2 = 0.121$, $F(3, 14) = 0.506$, $p = 0.686$.

Gaze direction (*Directed to Person, Directed to Object* and *Not-Directed*) prior to, during, and after vocalizations, and infant age at 8, 10, 12, 14, and 16 months did not significantly contribute to the multiple regression model for receptive vocabulary at 1 ½ years.

Expressive Vocabulary at 2 Years

Table 5 summarizes the descriptive statistics and analysis results when examining the relationship between expressive vocabulary at 2 years with all potential predictor variables. As can be seen, gazes directed to a person after utterances at 14 months were positively and significantly correlated with expressive vocabulary at 2 years of age, indicating that higher values in this category were related to a larger expressive vocabulary. Expressive vocabulary at 2 years of age was not significantly correlated with any of the other predictor variables.

The multiple regression model with all predictors at 8 months of age before utterances produced an $R^2 = 0.149$, $F(3, 14) = 0.643$, $p = 0.603$, during utterances produced an $R^2 = 0.162$, $F(3, 14) = 0.710$, $p = 0.566$, and after utterances produced an $R^2 = 0.171$, $F(3, 14) = 0.757$, $p = 0.541$; at 10 months of age, before utterances produced an $R^2 = 0.123$, $F(3, 14) = 0.514$, $p = 0.681$, during utterances produced an $R^2 = 0.045$, $F(3, 14) = 0.174$, $p = 0.911$, and after utterances produced an $R^2 = 0.146$, $F(3, 14) = 0.627$, $p = 0.612$; at 12 months of age, before utterances produced an $R^2 = 0.270$, $F(3, 14) = 1.354$, $p = 0.308$, during utterances produced an $R^2 = 0.081$, $F(3, 14) = 0.323$, $p = 0.809$, and after utterances produced an $R^2 = 0.369$, $F(3, 14) = 2.142$, $p = 0.153$; at 14 months of age, before utterances produced an $R^2 = 0.308$, $F(3, 14) = 1.632$, $p = 0.238$, during utterances produced an $R^2 = 0.283$, $F(3, 14) = 1.445$, $p = 0.283$, and after utterances produced an $R^2 = 0.372$, $F(3, 14) = 2.171$, $p = 0.149$; and at 16 months of age, before utterances produced an $R^2 = 0.313$, $F(3, 14) = 1.672$, $p = 0.230$, during utterances produced an $R^2 = 0.252$, $F(3, 14) = 1.236$, $p = 0.343$, and after utterances produced an $R^2 = 0.327$, $F(3, 14) = 1.778$, $p = 0.209$.

Gaze direction (*Directed to Person, Directed to Object* and *Not-Directed*) prior to, during, and after vocalizations, and infant age at 8, 10, 12, 14, and 16 months did not significantly contribute to the multiple regression model for expressive vocabulary at 2 years.

Expressive Vocabulary at 3 Years

Table 6 summarizes the descriptive statistics and analysis results when examining the relationship between expressive vocabulary at 3 years with all potential predictor variables. As can be seen, gazes directed to a person before utterances at 16 months were negatively and significantly correlated with expressive vocabulary at 3 years of age, indicating that higher values in this category were related to a smaller expressive vocabulary. Expressive vocabulary at 3 years of age was not significantly correlated with any of the other predictor variables.

The multiple regression model with all predictors at 8 months of age before utterances produced an $R^2 = 0.045$, $F(3, 14) = 0.173$, $p = 0.912$, during utterances produced an $R^2 = 0.074$, $F(3, 14) = 0.292$, $p = 0.830$, and after utterances produced an $R^2 = 0.031$, $F(3, 14) = 0.119$, $p = 0.947$; at 10 months of age, before utterances produced an $R^2 = 0.118$, $F(3, 14) = 0.491$, $p = 0.696$, during utterances produced an $R^2 = 0.139$, $F(3, 14) = 0.591$, $p = 0.634$, and after utterances produced an $R^2 = 0.122$, $F(3, 14) = 0.510$, $p = 0.684$; at 12 months of age, before utterances produced an $R^2 = 0.095$, $F(3, 14) = 0.383$, $p = 0.767$, during utterances produced an $R^2 = 0.228$, $F(3, 14) = 1.080$, $p = 0.398$, and after utterances produced an $R^2 = 0.133$, $F(3, 14) = 0.560$, $p = 0.652$; at 14 months of age, before utterances produced an $R^2 = 0.160$, $F(3, 14) = 0.698$, $p = 0.572$, during utterances produced an $R^2 = 0.125$, $F(3, 14) = 0.522$, $p = 0.676$, and after utterances produced an $R^2 = 0.134$, $F(3, 14) = 0.568$, $p = 0.648$; and at 16 months of age, before utterances produced an $R^2 = 0.470$, $F(3, 14) = 3.255$, $p = 0.064$, during utterances produced an $R^2 = 0.210$, $F(3, 14) = 0.972$, $p = 0.440$, and after utterances produced an $R^2 = 0.347$, $F(3, 14) = 1.945$, $p = 0.181$.

Gaze direction (*Directed to Person, Directed to Object* and *Not-Directed*) prior to, during, and after vocalizations, and infant age at 8, 10, 12, 14, and 16 months did not significantly contribute to the multiple regression model for expressive vocabulary at 3 years.

Effect Size.

While the majority of analyses conducted resulted in statistically nonsignificant findings, large effect sizes were found between most criterion and predictor variables, as can be seen in

Table 7 (with criterion variables listed horizontally and predictor variables listed vertically). This means that the majority of the differences between variables were large, implying strong relationships and suggesting clinical importance. While effect sizes were large across all criterion variables, they were particularly substantial between all predictor variables and expressive vocabulary at 3 years of age.

Discussion

Vocabulary growth is crucial for a child's language development; however, there is considerable variability in vocabulary growth throughout development (Cartmill et al., 2013; Mayor & Plunkett 2011; Rowe, Özçalişkan, & Goldin-Meadow, 2008). Many prelinguistic skills, as well as other aspects of an infant's development, are responsible for this variability (Mayor & Plunkett, 2011; Rowe et al., 2008). Research has shown the importance of prelinguistic communication and the ability to use it as one factor in predicting later language outcomes. As prelinguistic skills develop, early social communication skills in infants, such as joint attention, are more readily carried out and provide the child with the building blocks necessary for later language learning and development.

The results of the present study support previous findings by showing a relationship between gaze-direction and later vocabulary development. While the results only indicated statistically significant findings between a couple of the variables, the effect sizes were large between almost all variables. While effect size does not imply statistical significance, there is some indication of clinical significance. Implications of the correlation and multiple regression analysis, along with effect size results, will be discussed further.

Implications

Correlation Analysis. The correlation analysis indicated statistically significant correlations for two variables. The first significant correlation was found at 2 years of age; gazes directed at a person after utterances at 14 months were positively and significantly correlated with vocabulary. This finding supports previously discussed research that found prelinguistic acts were related to later vocabulary development. The second was found at 3 years of age which indicated that larger values in gazes directed to a person before utterances at 16 months of age were related to smaller expressive vocabulary values. This finding contradicts previous research and may be a result of the subjectivity of the coding. For codes *Directed to Person,* lab workers were to code at their own discretion which could have skewed the results in either direction.

Multiple Regression Analysis. The multiple regression analysis resulted in no statistically significant results. However, researchers have suggested that clinicians and clinical researchers should not only focus on statistically significant findings, but clinically significant findings as well, and one of the most important factors of clinical significance is effect size (Page, 2014).

Effect Size. The effect sizes between all predictor and criterion variables were medium (0.5-0.8) to large (greater than 0.8) and these effect sizes went up substantially at 3 years of age (all above 18) for expressive vocabulary. In addition, the effect sizes for receptive vocabulary were much larger than the effect sizes for expressive vocabulary at the same age and even slightly larger than expressive vocabulary at 2 years of age. These results follow the same pattern you see in typical development where receptive vocabulary is usually developed prior to expressive vocabulary. Overall, the clinical importance of these results is that infant gaze direction, whether before, during, or after utterances contributes to future vocabulary size in this group of children who are typically developing. The only exceptions observed to this fact were differences between means for gazes directed to an object before and after utterances at 12, 14, and 16 months of age and expressive vocabulary at 1.5 years of age.

Vocalizations, Gaze Direction, and Vocabulary Across Age Groups. The primary results of this study indicated that as the infant aged, the number of vocalizations increased both within and across infant age. Similarly, the expressive vocabulary increased with infant age, which is consistent with typical developmental norms. A pattern of increased receptive vocabulary could not be seen due to only having data on receptive vocabulary at one age. The initial data also suggested that the majority of gazes were directed to objects before, during, and after utterances, which may be a pattern to look into further in future research.

Limitations and Future Directions

While clinical relevance was accounted for through the effect size, statistical significance was not found for the majority of variables. To calculate statistical significance, the sample size is considered. The sample size of 15 infants is small and could be a contributing factor for the absence of statistical significance. In addition, the sample came from one area of the country, the area surrounding ECU. It would be beneficial to do similar research with a larger sample size from a more diverse area in order to support the findings of this study and increase the reliability and generalization of the results into clinical practice.

Further, this study only examined receptive vocabulary at 1.5 years of age. It would be beneficial to look at later receptive vocabulary and see if it follows the same pattern of increased effect size as expressive vocabulary, with a substantial increase at 3 years of age; especially since there have been other studies that focus on receptive vocabulary that have found prelinguistic acts of infants to be a factor in a child's later receptive vocabulary development (Brooks &

Meltzolf, 2005). In addition, this study demonstrated a larger effect size for receptive vocabulary than expressive vocabulary at 1.5 years of age. It would be beneficial to continue research of receptive vocabulary to determine if this pattern is similar across infant ages.

Furthermore, this study aimed to collect data based upon observation, rather than expensive eye-tracking equipment. In using an observer-based classification system, you risk human error, which could effect results. The current study defined infant gaze direction using only four codes, resulting in a very broad definition of each code, especially for the *Not Directed* code. Though all laboratory workers were trained in coding gaze direction, there was flexibility for classifying gaze type at the coder's discretion which resulted in an increase of subjectivity. The broad definitions and subjectivity could have impacted the results which indicated that gazes classified as *Not Directed* were related to a higher expressive vocabulary, which contradicts some of the previous literature discussed. Future research should be done with more descriptive codes (i.e., *directed to toy, directed to furniture, directed to wall, etc.)* to lessen the risk of subjectivity. However, using an observer-based classification system will always result in some form of subjectivity.

Lastly, we did not control for caregiver reaction to the infants' vocalization and/or gaze, which could have been a contributing factor to the infants' later vocabulary development. As Goldstein and colleagues discussed, prelinguistic acts could be a sign of readiness to learn, which tells the caregiver when and how to react (2010). Similarly, in one study, it was suggested that language development could be facilitated by social engagement (Tenenbaum, Sobel, Sheinkopf, Malle, & Morgan, 2015). Another group of researchers stated that "understanding young children's signals is critical to promote mutuality in the parent-child relationship" (Vallotton, Mastergeorge, Foster, Decker, & Ayoub, 2017). Their research indicated that enhancing the caregiver's responsiveness to an infant's cues was an important aspect of intervention since the caregiver's response aided in the development of skills necessary for language development. The mentioned findings show that prelinguistic communication, such as gaze direction, and caregiver interaction are intricately linked in a child's language development. Further research delineating the two would be beneficial. This information could aid in determining how caregiver response might change the gaze direction results seen in the present study.

Conclusion

Based upon the findings of Goldstein and colleagues (2010) that an infant's ODVs aid learning and through the findings of Brooks and Meltzoff (2005) that indicate gaze-following can predict vocabulary comprehension, we expected the overall outcomes to show a relationship between the directionality of an infant's gaze before, during, and after spontaneous vocalization and his or her later expressive and receptive vocabulary development. Our results indicated clinical significance, but no statistical significance. If studied further, these results could have an important positive impact by informing researchers and clinicians about factors that are impacting later development. Strategies to facilitate vocabulary development through early gaze direction could then be established. In addition, clinicians could be trained to implement similar observer-based classification systems to identify these early risks.

Clinical application. Prelinguistic acts, such as pointing, gaze direction, and gestures, can be used in part to identify infants at-risk for developmental delay with respect to speech and language (Brooks & Meltzoff, 2005; Brooks & Meltzoff, 2008; Tenenbaum et al. 2015). These acts can serve as an indicator of future vocabulary growth, or lack thereof. Early identification of language delay can aid the caregiver in accessing resources, such as the services of an SLP, to learn how to scaffold the child's language learning. This intervention would aid the parent in responding effectively and would optimize the child's language opportunities, increasing his or her likelihood for vocabulary growth. This type of caregiver education holds an important role in early intervention, and according to the American Speech-Language Hearing Association (ASHA, 2008), educating the caregiver is one of the roles of an SLP working in early intervention.

Early intervention. Educating families and clients is one aspect of early intervention. Another is helping children develop effective early communication skills. Communication is a major component of everyday life. One must be able to communicate effectively in social interactions, as well as in a learning environment (ASHA, 2008). The ability to communicate begins in infancy. Because later language development can be predicted from an infant's prelinguistic acts, parents and clinicians should be aware of these prelinguistic signs of communication, and more importantly the lack thereof, in order to identify those in need of early intervention services.

If clinicians and parents were able to identify children who are at-risk during the prelinguistic stage of communication, treatment could be implemented sooner, thus establishing a better prognosis for the child. Though other factors are involved, prelinguistic acts can be used to predict later vocabulary development, validating the possible use of gaze direction as one factor in determining possible language delay in infants. Speech-language pathologists could then intervene and educate families on the importance of caregiver responsiveness. In addition, SLPs could help with any other early intervention techniques, such as strategies to facilitate vocabulary development through early gaze direction, to allow the child the best chance at effective communication.

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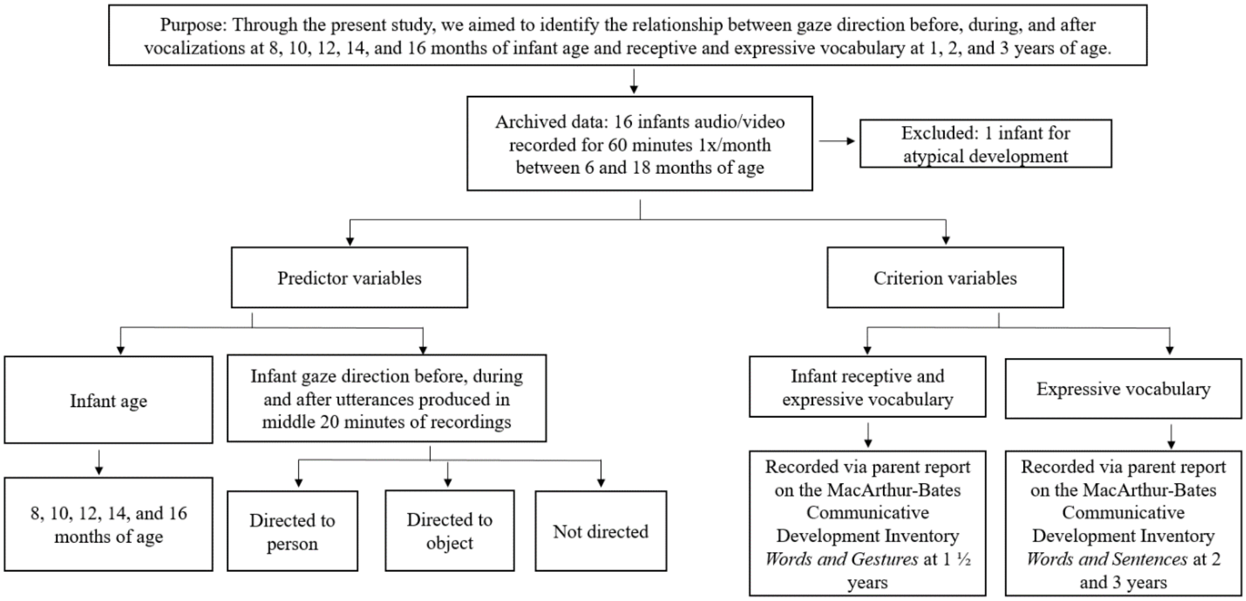

Figure 1. Purpose, participants, and variables of interest.

Table 1

Number of Utterances per Predictor Variable across Infants

Predictor Variables		Infant Age (in months)					
Gaze Location	Gaze Direction	8	10	12	14	16	Total
Before Utterance	Person	360	414	299	323	375	1771
	Object	490	581	854	855	987	3767
	Not	287	365	329	327	266	1574
During Utterance	Person	440	483	468	430	523	2344
	Object	432	464	698	660	789	3043
	Not	270	408	321	415	300	1714
After Utterance	Person	336	394	346	357	392	1825
	Object	513	588	826	841	996	3764
	Not	288	376	307	305	244	1520

Table 2
Vocabulary Size by Infants across Ages

Infant	1.5 Year Expressive	1.5 years Receptive	2 Years Expressive	3 Years Expressive
1	149	283	549	680
2	151	275	554	663
3	17	213	178	645
4	299	365	577	677
5	181	301	578	635
6	32	267	213	650
7	63	130	277	661
8	5	57	364	563
9	48	177	186	660
10	31	405	222	654
11	16	216	66	678
12	32	215	521	624
13	68	230	364	654
14	20	274	294	650
15	67	307	515	661
M	79	248	364	650
SD	82	87	173	29

Table 3

Summary Statistics, Correlations, and Results from the Regression Analysis (Dependent Variable = Expressive Vocabulary at 1 ½ years)

Predictor Variables						Multiple Regression Weights			
Gaze Location	Infant Age	Gaze Direction	*M*	*SD*	*r* (Pearson Correlation)	*B*	*β*	*t*	*p* (sig)
Before Utterance	8 Months	Person	24.00	16.80	-0.02	-0.65	-0.13	-0.47	0.65
		Object	32.67	19.06	-0.17	-0.73	-0.17	-0.63	0.54
		Not	19.13	11.60	0.39	3.03	0.43	1.51	0.16
	10 Months	Person	27.60	19.93	-0.04	0.03	0.01	0.02	0.99
		Object	38.73	25.10	-0.06	-0.11	-0.03	-0.10	0.92
		Not	24.33	19.19	-0.08	-0.30	-0.07	-0.16	0.87
	12 Months	Person	19.93	13.64	0.26	3.67	0.61	1.82	0.10
		Object	56.93	30.50	-0.09	-0.34	-0.13	-0.48	0.64
		Not	21.93	25.09	-0.16	-1.73	-0.53	-1.58	0.14
	14 Months	Person	21.53	11.51	0.32	2.14	0.30	0.87	0.41
		Object	57.00	35.37	0.20	-0.14	-0.06	-0.16	0.88
		Not	21.80	12.51	0.23	1.00	0.15	0.45	0.66
	16 Months	Person	25.00	13.83	0.05	0.31	0.05	0.18	0.86
		Object	65.80	34.29	0.26	0.88	0.37	1.22	0.25
		Not	17.73	9.54	-0.17	-2.80	-0.33	-1.06	0.31
During Utterance	8 Months	Person	29.33	14.93	0.02	-0.68	-0.12	-0.42	0.69
		Object	28.80	19.94	-0.19	-0.56	-0.14	-0.49	0.63
		Not	18.00	10.99	0.41	3.31	0.44	1.51	0.16
	10 Months	Person	32.20	22.07	-0.05	-0.10	-0.03	-0.07	0.95
		Object	30.93	21.04	-0.03	-0.08	-0.02	-0.06	0.95
		Not	27.20	20.65	-0.05	-0.13	-0.03	-0.09	0.93
	12 Months	Person	31.20	23.26	0.17	1.96	0.56	1.41	0.19
		Object	46.53	25.99	-0.21	-0.85	-0.27	-0.97	0.35
		Not	21.40	17.95	-0.09	-2.09	-0.46	-1.18	0.26
	14 Months	Person	28.67	13.25	0.41	2.49	0.40	1.04	0.32
		Object	44.00	28.78	0.08	-0.27	-0.09	-0.29	0.78
		Not	27.67	19.61	0.29	0.25	0.06	0.14	0.89
	16 Months	Person	34.87	14.00	0.08	0.14	0.02	0.07	0.94
		Object	52.60	30.26	0.26	0.86	0.32	0.99	0.34
		Not	20.00	9.54	-0.10	-1.86	-0.22	-0.69	0.50
After Utterance	8 Months	Person	22.40	15.81	0.01	-0.33	-0.06	-0.23	0.82
		Object	34.20	20.16	-0.17	-0.90	-0.22	-0.80	0.44
		Not	19.20	11.47	0.35	2.86	0.40	1.42	0.18
	10 Months	Person	26.27	19.45	-0.07	-0.46	-0.11	-0.28	0.79
		Object	39.20	23.26	-0.03	-0.19	-0.05	-0.16	0.88
		Not	25.07	19.53	-0.02	0.26	0.06	0.15	0.89
	12 Months	Person	23.07	14.57	0.35	3.68	0.65	2.27	0.04
		Object	55.07	28.93	-0.13	-0.46	-0.16	-0.64	0.53
		Not	20.47	23.81	-0.20	-1.74	-0.50	-1.75	0.11
	14 Months	Person	23.80	12.76	0.47	3.14	0.49	1.65	0.13
		Object	56.07	37.10	0.15	-0.19	-0.09	-0.28	0.79
		Not	20.33	11.97	0.18	0.45	0.07	0.22	0.83
	16 Months	Person	26.13	15.46	0.19	0.77	0.15	0.46	0.65
		Object	66.40	32.24	0.22	0.54	0.21	0.67	0.52
		Not	16.27	9.76	-0.19	-2.17	-0.26	-0.89	0.39

*p < .05, **p < .01, ***p < .001

Table 4

Summary Statistics, Correlations, and Results from the Regression Analysis (Dependent Variable = Receptive Vocabulary at 1 ½ years)

Predictor Variables			*M*	*SD*	*r* (Pearson Correlation)	Multiple Regression Weights		*t*	*p* (sig)
Gaze Location	Infant Age	Gaze Direction				*B*	*β*		
Before Utterance	8 Months	Person	24.00	16.80	0.05	-0.18	-0.04	-0.12	0.90
		Object	32.67	19.06	-0.29	-1.33	-0.29	-1.08	0.30
		Not	19.13	11.60	0.34	2.71	0.36	1.28	0.23
	10 Months	Person	27.60	19.93	-0.31	-1.56	-0.36	-0.91	0.38
		Object	38.73	25.10	-0.14	-0.58	-0.17	-0.53	0.61
		Not	24.33	19.19	-0.21	0.31	0.07	0.16	0.87
	12 Months	Person	19.93	13.64	-0.08	0.99	0.16	0.43	0.68
		Object	56.93	30.50	-0.28	-0.77	-0.27	-0.95	0.36
		Not	21.93	25.09	-0.24	-1.06	-0.30	-0.85	0.42
	14 Months	Person	21.53	11.51	0.11	0.38	0.05	0.14	0.89
		Object	57.00	35.37	0.14	0.16	0.06	0.16	0.88
		Not	21.80	12.51	0.13	0.53	0.08	0.21	0.84
	16 Months	Person	25.00	13.83	-0.24	-1.94	-0.31	-1.04	0.32
		Object	65.80	34.29	-0.09	-0.37	-0.15	-0.48	0.64
		Not	17.73	9.54	0.20	3.20	0.35	1.14	0.28
During Utterance	8 Months	Person	29.33	14.93	0.17	0.98	0.17	0.55	0.59
		Object	28.80	19.94	-0.30	-1.41	-0.32	-1.14	0.28
		Not	18.00	10.99	0.25	1.33	0.17	0.56	0.59
	10 Months	Person	32.20	22.07	-0.29	-1.21	-0.31	-0.89	0.39
		Object	30.93	21.04	-0.17	-0.69	-0.17	-0.55	0.59
		Not	27.20	20.65	-0.17	0.24	0.06	0.15	0.88
	12 Months	Person	31.20	23.26	-0.11	0.47	0.13	0.32	0.76
		Object	46.53	25.99	-0.40	-1.34	-0.40	-1.42	0.18
		Not	21.40	17.95	-0.17	-1.01	-0.21	-0.53	0.61
	14 Months	Person	28.67	13.25	0.21	1.77	0.27	0.65	0.53
		Object	44.00	28.78	0.09	0.18	0.06	0.17	0.87
		Not	27.67	19.61	0.11	-0.52	-0.12	-0.25	0.81
	16 Months	Person	34.87	14.00	-0.21	-1.93	-0.31	-1.01	0.34
		Object	52.60	30.26	-0.13	-0.40	-0.14	-0.46	0.66
		Not	20.00	9.54	0.26	3.87	0.42	1.43	0.18
After Utterance	8 Months	Person	22.40	15.81	0.01	-0.36	-0.07	-0.24	0.81
		Object	34.20	20.16	-0.26	-1.37	-0.32	-1.19	0.26
		Not	19.20	11.47	0.37	3.27	0.43	1.58	0.14
	10 Months	Person	26.27	19.45	-0.30	-1.55	-0.34	-0.93	0.37
		Object	39.20	23.26	-0.14	-0.58	-0.16	-0.49	0.64
		Not	25.07	19.53	-0.19	0.33	0.07	0.19	0.86
	12 Months	Person	23.07	14.57	0.04	1.90	0.32	1.01	0.33
		Object	55.07	28.93	-0.33	-0.94	-0.31	-1.13	0.28
		Not	20.47	23.81	-0.29	-1.40	-0.38	-1.22	0.25
	14 Months	Person	23.80	12.76	0.22	1.47	0.21	0.65	0.53
		Object	56.07	37.10	0.11	0.06	0.03	0.08	0.94
		Not	20.33	11.97	0.06	-0.13	-0.02	-0.05	0.96
	16 Months	Person	26.13	15.46	-0.06	-0.02	0.00	-0.01	0.99
		Object	66.40	32.24	-0.18	-0.67	-0.25	-0.78	0.45
		Not	16.27	9.76	0.25	2.72	0.30	1.05	0.32

*p < .05, **p < .01, ***p < .001

Table 5

Summary Statistics, Correlations, and Results from the Regression Analysis (Dependent Variable = Expressive Vocabulary at 2 years)

Predictor Variables			*M*	*SD*	*r* (Pearson Correlation)	Multiple Regression Weights		*t*	*p* (sig)
Gaze Location	Infant Age	Gaze Direction				*B*	*β*		
Before Utterance	8 Months	Person	24.00	16.80	-0.12	-2.44	-0.24	-0.81	0.43
		Object	32.67	19.06	0.16	1.54	0.17	0.61	0.55
		Not	19.13	11.60	0.27	5.09	0.34	1.18	0.26
	10 Months	Person	27.60	19.93	-0.01	1.69	0.20	0.50	0.63
		Object	38.73	25.10	0.28	2.65	0.39	1.22	0.25
		Not	24.33	19.19	-0.05	-2.73	-0.30	-0.74	0.48
	12 Months	Person	19.93	13.64	0.11	6.40	0.51	1.52	0.16
		Object	56.93	30.50	0.07	0.39	0.07	0.26	0.80
		Not	21.93	25.09	-0.32	-4.45	-0.65	-1.96	0.08
	14 Months	Person	21.53	11.51	0.47	5.80	0.39	1.26	0.23
		Object	57.00	35.37	0.34	-0.33	-0.07	-0.20	0.85
		Not	21.80	12.51	0.44	4.64	0.34	1.11	0.29
	16 Months	Person	25.00	13.83	0.34	3.49	0.28	1.05	0.31
		Object	65.80	34.29	0.48	2.42	0.48	1.77	0.10
		Not	17.73	9.54	0.06	-3.66	-0.20	-0.73	0.48
During Utterance	8 Months	Person	29.33	14.93	-0.04	-2.54	-0.22	-0.72	0.49
		Object	28.80	19.94	0.05	1.06	0.12	0.43	0.68
		Not	18.00	10.99	0.34	6.79	0.43	1.44	0.18
	10 Months	Person	32.20	22.07	0.00	-0.36	-0.05	-0.13	0.90
		Object	30.93	21.04	0.21	1.56	0.19	0.61	0.55
		Not	27.20	20.65	0.10	0.53	0.06	0.17	0.87
	12 Months	Person	31.20	23.26	0.01	2.26	0.31	0.72	0.48
		Object	46.53	25.99	-0.03	-0.28	-0.04	-0.14	0.89
		Not	21.40	17.95	-0.19	-3.89	-0.41	-0.98	0.35
	14 Months	Person	28.67	13.25	0.51	4.75	0.37	1.01	0.33
		Object	44.00	28.78	0.25	0.08	0.01	0.04	0.97
		Not	27.67	19.61	0.46	1.76	0.20	0.50	0.63
	16 Months	Person	34.87	14.00	0.36	2.15	0.18	0.59	0.57
		Object	52.60	30.26	0.44	1.83	0.32	1.10	0.30
		Not	20.00	9.54	0.32	2.65	0.15	0.51	0.62
After Utterance	8 Months	Person	22.40	15.81	-0.15	-2.51	-0.23	-0.82	0.43
		Object	34.20	20.16	0.14	0.85	0.10	0.36	0.73
		Not	19.20	11.47	0.33	5.55	0.37	1.30	0.22
	10 Months	Person	26.27	19.45	-0.07	0.32	0.04	0.10	0.92
		Object	39.20	23.26	0.34	3.11	0.42	1.34	0.21
		Not	25.07	19.53	-0.02	-1.78	-0.20	-0.51	0.62
	12 Months	Person	23.07	14.57	0.25	6.92	0.58	2.06	0.06
		Object	55.07	28.93	0.01	0.18	0.03	0.12	0.91
		Not	20.47	23.81	-0.34	-4.74	-0.65	-2.31	0.04
	14 Months	Person	23.80	12.76	0.56*	6.60	0.49	1.83	0.09
		Object	56.07	37.10	0.31	-0.04	-0.01	-0.03	0.98
		Not	20.33	11.97	0.40	3.56	0.25	0.92	0.38
	16 Months	Person	26.13	15.46	0.46	3.70	0.33	1.20	0.25
		Object	66.40	32.24	0.47	1.93	0.36	1.30	0.22
		Not	16.27	9.76	-0.03	-2.97	-0.17	-0.66	0.52

*p < .05, **p < .01, ***p < .001

Table 6

Summary Statistics, Correlations, and Results from the Regression Analysis (Dependent Variable = Expressive Vocabulary at 3 years)

Predictor Variables						Multiple Regression Weights			
Gaze Location	Infant Age	Gaze Direction	*M*	*SD*	*r* (Pearson Correlation)	*B*	*β*	*t*	*p* (sig)
Before Utterance	8 Months	Person	24.00	16.80	0.11	0.08	0.05	0.15	0.89
		Object	32.67	19.06	0.07	0.09	0.06	0.20	0.85
		Not	19.13	11.60	0.20	0.46	0.18	0.60	0.56
	10 Months	Person	27.60	19.93	0.04	0.15	0.11	0.27	0.79
		Object	38.73	25.10	-0.33	-0.34	-0.29	-0.93	0.37
		Not	24.33	19.19	-0.14	-0.17	-0.11	-0.27	0.79
	12 Months	Person	19.93	13.64	0.26	0.77	0.37	0.99	0.34
		Object	56.93	30.50	0.11	0.07	0.08	0.26	0.80
		Not	21.93	25.09	0.05	-0.21	-0.19	-0.51	0.62
	14 Months	Person	21.53	11.51	-0.17	-0.94	-0.37	-1.11	0.29
		Object	57.00	35.37	0.12	0.13	0.17	0.44	0.67
		Not	21.80	12.51	0.26	0.69	0.30	0.90	0.39
	16 Months	Person	25.00	13.83	-0.63*	-1.51	-0.73	-3.12	0.01
		Object	65.80	34.29	0.04	0.13	0.16	0.67	0.52
		Not	17.73	9.54	0.02	0.54	0.18	0.73	0.48
During Utterance	8 Months	Person	29.33	14.93	0.09	-0.05	-0.03	-0.09	0.93
		Object	28.80	19.94	0.05	0.11	0.07	0.25	0.81
		Not	18.00	10.99	0.26	0.73	0.28	0.87	0.40
	10 Months	Person	32.20	22.07	0.03	0.31	0.24	0.69	0.50
		Object	30.93	21.04	-0.25	-0.21	-0.16	-0.53	0.61
		Not	27.20	20.65	-0.27	-0.49	-0.35	-0.98	0.35
	12 Months	Person	31.20	23.26	0.33	0.86	0.69	1.80	0.10
		Object	46.53	25.99	0.02	-0.08	-0.07	-0.27	0.80
		Not	21.40	17.95	0.00	-0.79	-0.49	-1.29	0.22
	14 Months	Person	28.67	13.25	-0.15	-0.93	-0.43	-1.08	0.30
		Object	44.00	28.78	0.18	0.16	0.17	0.50	0.63
		Not	27.67	19.61	0.10	0.46	0.31	0.71	0.49
	16 Months	Person	34.87	14.00	-0.42	-1.06	-0.52	-1.70	0.12
		Object	52.60	30.26	-0.06	0.11	0.12	0.39	0.70
		Not	20.00	9.54	-0.02	0.38	0.13	0.43	0.68
After Utterance	8 Months	Person	22.40	15.81	0.13	0.19	0.11	0.35	0.73
		Object	34.20	20.16	0.07	0.08	0.05	0.18	0.86
		Not	19.20	11.47	0.13	0.26	0.10	0.34	0.74
	10 Months	Person	26.27	19.45	0.07	0.23	0.15	0.42	0.68
		Object	39.20	23.26	-0.33	-0.35	-0.28	-0.89	0.39
		Not	25.07	19.53	-0.15	-0.19	-0.13	-0.33	0.75
	12 Months	Person	23.07	14.57	0.32	0.82	0.42	1.25	0.24
		Object	55.07	28.93	0.09	0.04	0.04	0.14	0.89
		Not	20.47	23.81	0.02	-0.25	-0.21	-0.63	0.54
	14 Months	Person	23.80	12.76	-0.17	-0.72	-0.32	-1.02	0.33
		Object	56.07	37.10	0.13	0.12	0.16	0.48	0.64
		Not	20.33	11.97	0.22	0.62	0.26	0.81	0.43
	16 Months	Person	26.13	15.46	-0.49	-1.14	-0.61	-2.25	0.05
		Object	66.40	32.24	-0.04	0.15	0.17	0.61	0.56
		Not	16.27	9.76	0.20	0.78	0.27	1.06	0.31

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Table 7

Effect Sizes (Cohen's d) between Criterion and Predictor Variables

Predictor Variables: Gaze Location	Infant Age	Gaze Direction	Expressive Vocabulary at 1.5 Year	Receptive Vocabulary at 1.5 Year	Expressive Vocabulary at 2 Years	Expressive Vocabulary at 3 Years
Before Utterance	8 Months	Person	0.93	3.56	2.77	26.61
		Object	0.78	3.40	2.69	25.34
		Not	1.03	3.67	2.82	28.81
	10 Months	Person	0.87	3.48	2.73	25.19
		Object	0.67	3.25	2.63	22.68
		Not	0.92	3.53	2.76	25.62
	12 Months	Person	1.01	3.64	2.81	28.03
		Object	0.36	2.92	2.47	20.03
		Not	0.95	3.51	2.77	23.30
	14 Months	Person	0.99	3.63	2.80	28.73
		Object	0.35	2.86	2.46	18.42
		Not	0.98	3.62	2.79	28.36
	16 Months	Person	0.92	3.56	2.76	27.73
		Object	0.21	2.74	2.39	18.49
		Not	1.05	3.70	2.83	29.55
During Utterance	8 Months	Person	0.85	3.49	2.73	27.12
		Object	0.85	3.46	2.72	25.14
		Not	1.05	3.69	2.83	29.07
	10 Months	Person	0.78	3.38	2.69	24.13
		Object	0.81	3.41	2.70	24.60
		Not	0.87	3.48	2.74	24.91
	12 Months	Person	0.80	3.39	2.70	23.69
		Object	0.54	3.12	2.57	22.05
		Not	0.98	3.59	2.79	26.26
	14 Months	Person	0.86	3.51	2.74	27.79
		Object	0.57	3.13	2.58	21.09
		Not	0.87	3.48	2.73	25.32
	16 Months	Person	0.76	3.40	2.68	27.23
		Object	0.43	2.99	2.51	20.26
		Not	1.02	3.67	2.81	29.44
After Utterance	8 Months	Person	0.96	3.59	2.78	27.08
		Object	0.76	3.37	2.68	24.83
		Not	1.03	3.67	2.81	28.85
	10 Months	Person	0.89	3.50	2.75	25.44
		Object	0.67	3.26	2.63	23.38
		Not	0.91	3.52	2.76	25.45
	12 Months	Person	0.95	3.59	2.78	27.54
		Object	0.39	2.96	2.49	20.65
		Not	0.97	3.55	2.78	23.87
	14 Months	Person	0.95	3.59	2.78	28.18
		Object	0.36	2.86	2.46	17.92
		Not	1.01	3.65	2.80	28.62
	16 Months	Person	0.90	3.53	2.75	27.06
		Object	0.21	2.75	2.39	19.13
		Not	1.08	3.72	2.84	29.55