The Reorganization of Communicative Behaviors around the Onset of the Vocabulary Spurt: A Dynamic Systems Approach

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This study investigated the reorganization of communicative behaviors during the window of time surrounding the vocabulary spurt by considering the relationship between language, gesture, and affect as the communicative system undergoes a period of instability. Eighteen typically developing infants were videotaped with a primary caregiver at home one month before, at, and one month after the onset of the vocabulary spurt. There were significant differences between the vocabulary spurt session and surrounding sessions in terms of the production and temporal patterning of expressive behaviors. Specifically, the coordination of communicative behaviors occurred less frequently; speech was particularly unlikely to appear in coordination with other behaviors; and the use of earlier well-practiced configurations (e.g., affect combined with meaningless vocalizations) increased specifically at the spurt session. In addition, infants who experienced a more dramatic transition in vocabulary development showed evidence of greater system-wide instability at the vocabulary spurt onset. Findings underscore the importance of examining the communicative system as a whole and using a milestone-based dynamic systems approach to studying developmental change.

Keywords: vocabulary spurt; dynamic systems theory; communicative coordination

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PREFACE

This research was supported in part by a grant from the National Institute of Health (R01 HD41677) to Jana M. Iverson. Portions of these data were presented at the 2007 Biennial Meetings of the Society for Research in Child Development, Boston, MA.

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1.0 INTRODUCTION

A 12-month-old girl is happily splashing in the tub and playing with her toys while her father looks on. Reaching for her favorite bath toy, she looks at it, smiles widely, and then vocalizes excitedly while lifting it up for her father to see. A 15-month-old boy, seated on a park bench with his mother, points at a dog running by and says “ruf ruf” while turning an already smiling face to look up at his mother. A 17-month-old walks into the kitchen where his parents are preparing dinner, reaches first to the apple on the counter, then looks at his father and says “eat!” These examples illustrate that young children readily use facial expressions, vocalizations, gestures, and eventually speech, to interact with others. These expressive actions can be used in isolation or be combined to deliver a communicative message. The child’s increasing ability to coordinate expressions from different behavioral modalities into specific patterns is a crucial component in the development of communication. As children progress through communicative development, the integration and coupling of communicative expressions is directly observable; and it is this interplay among behaviors that highlights the dynamic organization of the communicative system. Thus, the overarching goal of the proposed research was to examine the relative impact of the onset of a major communicative milestone on the organization of the multiple constituent components of the communicative system.

1.1 A DYNAMIC SYSTEMS APPROACH

Dynamic systems theory (Thelen & Smith, 1994) provides a framework with which to consider the puzzles presented by normative development. This approach to studying development posits that in order to understand the complexity of change, one should focus on specific periods in development that are characterized by instability and inconsistency. Thus, points at which new behavioral forms begin to emerge, or points of transition, serve as windows into the underlying process of change.

According to the dynamic view, the developing system is always changing. This continual adaptation and flexibility is considered to be characteristic of complex organisms (Gershkoff-Stowe & Thelen, 2004; Iverson & Thelen, 1999; Thelen, 2000; Thelen & Smith, 1994). Hence a central question in dynamic systems theory is how complex systems, including developing infants, produce behavioral patterns that evolve over time. The multiple interacting components of the system cooperate together to produce coherent, self-organized behavior; it is in the mutual interactions and shifting coordination of these co-existing parts that we can observe the very process of change (Thelen, 2001).

Another fundamental assumption unique to the dynamic systems approach is that of soft-assembly (e.g., Thelen & Smith, 1994). Soft assembly is the notion that behavior is inherently flexible and that many different coordinations are possible based on the influence and relative stability of the constituent parts. At times of developmental transition, certain behavioral configurations may be more sensitive to change and more easily disrupted, while other patterns are more stable and resilient to change. Newly emerging forms tend to be in a state of greater vulnerability than well-established behavioral forms. Generally, components are free to assemble in other behavioral modes as the system moves through periods of instability to greater stability.

Practice is an important determinant of systemic configurations. As children practice emerging skills, the system regains stability, allowing novel skills to become integrated with other well-established skills. Thus, for example, 14-month-old infants (who are actively acquiring new words) can discriminate simple nonsense labels ("bih" vs. "dih") during a speech-perception task, in which the label is paired with a checkerboard pattern visual display, but have difficulty discriminating the same sound labels during a word-object association task, in which the nonsense word is paired with a brightly colored moving object (Stager & Werker, 1997). In contrast, 8-month-old infants (who have not yet acquired any words) are successful in differentiating the same phonetically similar sound patterns in the same word learning task in which infants aged 14 months failed. Thus, it is only at the time when infants are attempting to learn words that they fail to attend to phonetic information in a word learning task. Indeed, by 3 years of age, a time when word learning is no longer difficult, English-learning children can distinguish most similar sounding words (e.g., Barton, 1978). This pattern of failing to use existing skills during a time of instability or increased difficulty (i.e., word learning) is an example of functional reorganization in the language acquisition system (for additional examples from other domains see Adolph, 2000; Thelen, 2001). This reorganization both generates new behavioral forms and offers increasing stability to behaviors with a longer history of performance.

1.2 THE VOCABULARY SPURT AS A DEVELOPMENTAL TRANSITION

In their first few years of life, children undergo a number of developmental transitions that provide opportunities to observe rapid growth, reorganization, and instability. One such period in the area of language development that has captured researchers' interest for decades is the vocabulary spurt. The vocabulary spurt has been defined as a sudden, rapid increase in productive vocabulary that occurs at about 16 to 18 months of age, after children typically have an expressive language base of around 50 words (Bates, Bretherton, & Snyder, 1988; Bloom, 1973, Dromi, 1987; Gershkoff-Stowe & Smith, 1997; Goldfield & Reznick, 1990; Nelson, 1973). At this time, new words begin to be acquired at an extraordinarily rapid pace, with children's productive vocabularies often being observed to double within one month's time (e.g., Benedict, 1979; Bloom, Lifter, & Boughton, 1985; Carey, 1978; but see Ganger & Brent, 2004, for an alternative view). It is generally accepted that children's rate of vocabulary acquisition does not simply increase, but undergoes a discrete, qualitative and quantitative transition. At this point, children switch from an initial stage of slow vocabulary growth to a subsequent stage of faster growth.

Many developmentalists propose that the vocabulary spurt marks a significant advancement in children's conceptual knowledge and denotes major cognitive and linguistic change (Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979; Dapretto & Bjork, 2000; Gopnik & Meltzoff, 1987; Lifter & Bloom, 1989; Ninio, 1995; Plunkett, 1993). Although there is disagreement regarding the precise nature or meaning of the vocabulary spurt, there is a wide-spread acceptance of the vocabulary spurt as a milestone of linguistic and cognitive development (e.g., Bloom & Capatides, 1987; Choi & Gopnik, 1995; Gershkoff-Stowe & Smith, 1997) and as a marker of developmental change (e.g., Fisher, Pipp, & Bullock, 1984; Lifter & Bloom, 1989).

Although the vocabulary spurt is considered a time of impressive cognitive growth and developmental achievement, it is also a period of instability and enormous variability. Gershkoff-Stowe (2001, 2002) describes the period surrounding the vocabulary spurt as a time when children are especially susceptible to error, and in particular, naming errors. These errors most often involve the overextension of a known word to a novel object that is similar in appearance to the known word. For example, a child who wants to refer to a sheep but who does not know the name for that object might call the sheep “doggie.” In addition to overgeneralization errors, errors sometimes occur when children already have the correct word in their expressive vocabulary but produce the wrong word by mistake. These errors have been considered to reflect momentary failures in accessing the correct word rather than lack of word knowledge. Thus, for example, a child may point to a picture of a duck and correctly label it “duck.” However, soon after, the child may point to a picture of a shoe (an object also named correctly in the past) but may mistakenly refer to the shoe by saying the word “duck.” These naming errors tend to peak with the onset of accelerated vocabulary growth and, in Gershkoff-Stowe’s view, are most likely due to errors in retrieval (Dapretto & Bjork, 2000; Gershkoff-Stowe, 2001; Gershkoff-Stowe & Smith, 1997). Errors may occur as a result of heightened competition between newly acquired words and those more firmly established in the lexicon. In fact, Gershkoff-Stowe (2002) found that as individual words were practiced in production, they became stronger and more resistant to interference from lexical competitors.

In addition to being a period of instability, the vocabulary spurt is also characterized by variability. There are striking individual differences in the rate and shape of vocabulary development (e.g., Dale & Goodman, 2005). Data from a large longitudinal database, The San Diego Longitudinal Study (Goodman et al., 1999), indicate that although at the group level infants showed a typical pattern of word production development, that is, slow initial growth followed by a spurt in the rate of word learning, there were differences in how early the spurt began and in the steepness of the growth curve slopes. In fact, these authors depicted four distinct individual vocabulary growth trajectories within the sample that confirmed the "common pattern" of the vocabulary spurt (Fenson et al., 1994; Goodman et al., 1999): the typical spurt-fast rate; the typical spurt-slow rate; the hyperspurt; and two spurts (see Figure 1 for similar examples of individual differences from the participants in the present study).

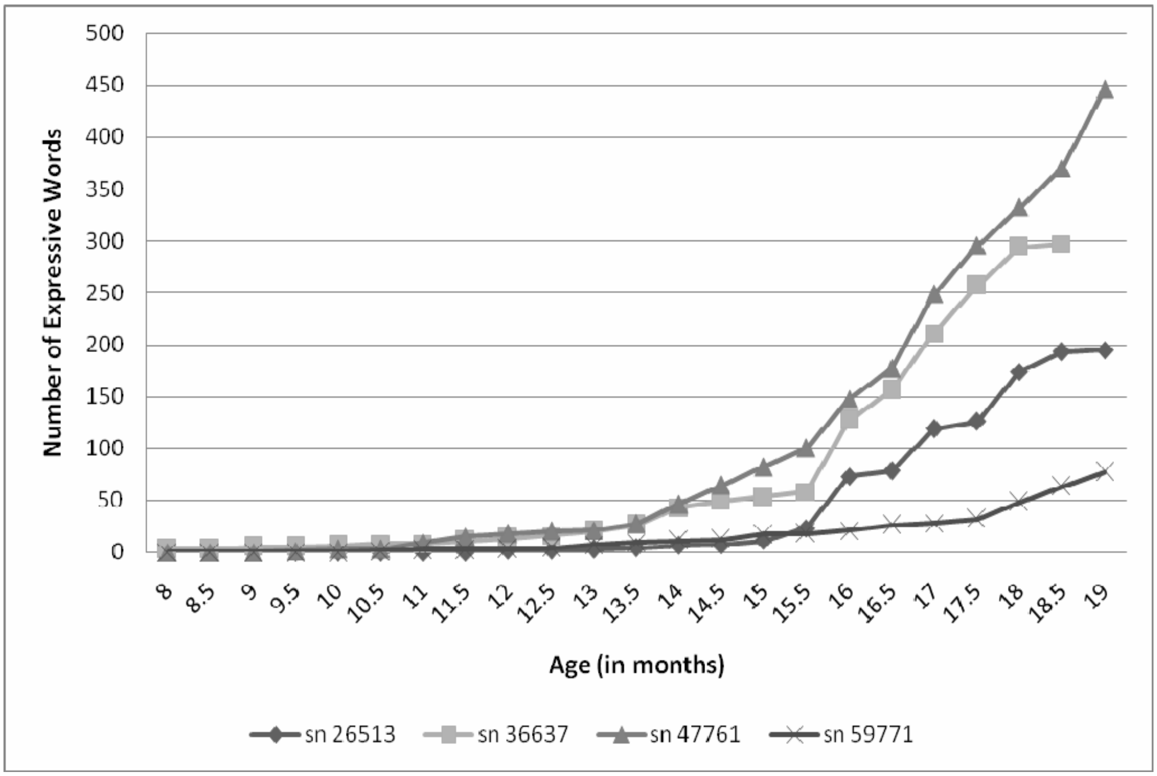

Figure 1 Individual patterns of children in the current study experiencing a vocabulary spurt according to a common inclusion criterion (i.e., increase of 10 words in two weeks after already having reached a base of 20 words).

Other studies have reported that not all individuals undergo the characteristic vocabulary spurt, and some demonstrate that only a minority of children do so (Ganger & Brent, 2004). Despite this variability, relatively little research has addressed the question of why some children achieve this communicative milestone and some do not. In one study, Goldfield and Reznick

(1990) found that those children who showed a more gradual vocabulary growth acquired a more varied lexicon encompassing multiple word classes, while children who experienced a vocabulary spurt focused their linguistic efforts on primarily learning nouns. A recent study directly examined the existence of a vocabulary spurt using statistical modeling (Ganger & Brent, 2004; see also van Geert, 1991). They argued that the vocabulary spurt as it is traditionally conceptualized should involve a discrete shift from an initial stage of slow vocabulary growth to a subsequent sustained stage of faster growth. Thus, if a child's learning rate undergoes a transition between a low stage and a high stage, it will be possible to identify a specific point in the learning rate curve where this transition occurs. Using longitudinal data, they modeled the rate of word learning with two statistical functions, a logistic function which involves an inflection point (i.e., a point where the rate of increase of a curve is greater than it is before or after), and a quadratic function without an inflection point. The authors found that only a minority of children actually showed a better fit for the logistic function suggesting that most children experience a more gradual increase in word learning rather than a discrete transition between two distinct stages. Nevertheless, factors that may contribute to variability in vocabulary acquisition remain relatively unstudied.

1.3 DYNAMIC SYSTEMS APPROACHES TO COMMUNICATIVE DEVELOPMENT

Dynamic systems theory has provided a fruitful approach to studying transitional periods in domains such as motor development and early word learning (e.g., Smith, 1995; Thelen, 2000; Thelen & Ulrich, 1991). To our knowledge, this approach has not yet been applied to empirical studies of early communication (for a theoretical application see Fogel & Thelen, 1987; van Geert, 1991). The ways in which infants communicate changes dramatically over the first few years of life. Developmentalists have studied the existence of communicative milestones that transcend specific modalities of expression, such as the transition from dyadic to triadic communication and from preverbal to verbal forms of communication (Fogel & Thelen, 1987). Early communication generally takes place within the context of dyadic situations or face-to-face exchanges with social partners. Between the ages of 2 and 6 months, young infants engage in finely-tuned interactions with their caregivers that are primarily characterized by social initiatives of affective facial expressions. These interactions include hallmarks of adult conversations, such as subtle turn-taking behavior and emotional co-regulation (Fogel, 1993; Stern, 1985) and have been linked to the emergence of later triadic communication (Striano & Rochat, 1999).

A major achievement in development is the emergence of intentional communication. Intentional communication refers to the use of prelinguistic signals to elicit an adult's attention to an object or event (Bates, 1979; Bates et al., 1979; Bruner, 1975; Harding & Golinkoff, 1979). Intentional communication for the young child is characterized by temporal coordination of various modes of expression, including facial expressions, vocalizations, gaze direction, and gestures (e.g., Bates, 1976; Bates et al., 1979). Infants' use of gestures for communication is thought to index the emergence of triadic communication, and the pointing gesture in particular has been considered a hallmark of communicative intentionality (Bates, 1976; Bates et al., 1979; Kita, 2003; Moore & Corkum, 1994; Moore & Dunham, 1995; Tomasello & Carpenter, 2005). However, communication continues to evolve as infants shift from preverbal to verbal communication. As infants' repertoire of communicative acts expands to include words, there is reorganization and a shift in the preferred mode of expression. Earlier forms of communication are altered as they support the systematic emergence of new forms; new modes emerge alongside well-established forms. A rich body of evidence has established the temporal and predictive links between these communicative modalities throughout the infancy period; these will be discussed in more detail in the following sections.

1.4 AFFECTIVE EXPRESSION IN EARLY COMMUNICATION

Emotional expression and language are two communicative systems available to the child in the second year of life and are thought to coexist as complementary systems of expression (Bloom, Beckwith, Capatides, & Hafitz, 1988). The link between these systems is apparent in young infants' systematic combination of behaviors from two modalities into specific temporal patterns. Yale and colleagues showed that as early as 3 months of age, infants coordinated facial expressions, such as smiles and frowns, with vocalizations at greater than chance levels (Yale, Messinger, Cobo-Lewis, Oller, & Eilers, 1999; Yale, Messinger, Cobo-Lewis, & Delgado, 2003). Work by Bloom and colleagues suggests that affective expression remains important at the time that first words begin to appear and is in fact the dominant form of expression at this point (Bloom, 1994; Bloom, Beckwith, & Capatides, 1987; Bloom & Capatides, 1987). They reported that frequency of emotional expression increased from 9 to 17 months for children who were later word learners (i.e., infants who achieved first word onset above the mean age of the group), but remained stable for early word learners (Bloom, Beckwith, & Capatides, 1987). Moreover, children who expressed emotion more frequently attained linguistic milestones (i.e., first word onset and vocabulary spurt; Bloom & Capatides, 1987) at later ages than children who remained more neutral in their affective expression. This line of work by Bloom and colleagues suggests that the expression of affect may play a hindering role in the acquisition of language. Thus, the expression of affect seems to be inherently tied to linguistic communication and may be related to individual variation in the achievement of developmental milestones.

Other researchers have also noted the occurrence of important developmental modifications in the timing and patterning of the affective and linguistic communication systems. For example, Adamson and Bakeman (1985) found that over time, episodes of affect became progressively briefer so that by 15-18 months, they were typically discrete periods of excitement lasting less than 2 seconds. The typical mode of expression also changed. At younger ages (6, 9, and 12 months), no single behavior exclusively characterized infants' expressive displays, but by the end of infancy (15 and 18 months), over 75% contained a vocal element, and the percentage of expressions involving a facial element decreased from over 50% to approximately 30%. Other research has reported that while frequency of word production increased over the word learning period, frequency of affective displays remained relatively constant over time (Bloom et al., 1988). The authors interpreted this stability in affect expression as indicating that words did not replace affect per se, but emerged as a new system for expressing additional information. Thus, affect and language begin to act as complementary systems of expression. It seems that infants do not abandon more "primitive" forms of communicative expression, but rather continue to draw upon their earlier-developing communication skills in ways that support the emergence of new skills.

1.5 THE GESTURE-SPEECH SYSTEM

Spoken language typically does not occur in isolation; rather, it is generally accompanied by a host of nonverbal behaviors. A growing body of research has established a tight link between language and gesture. It has been suggested that in adults, gesture and speech form a single, integrated system (e.g., McNeill, 1992, 2005). The strength of this link has been demonstrated in gesture suppression experiments and in studies of communication among blind individuals. First, narratives produced when gesturing is prohibited are more verbally dysfluent than those produced when gesturing is permitted (Rauscher, Krauss, & Chen, 1996). Further, gestures have been observed in congenitally blind speakers (Iverson, 1999; Iverson & Goldin-Meadow, 1997, 2001), even when interacting with another blind speaker (Iverson & Goldin Meadow, 1998). Gestures and speech also have a constant relationship in time, such that the movement phase, or stroke, of the gesture either slightly anticipates or occurs in synchrony with co-expressive speech (McNeill, 1992). This relationship persists even in the face of severe disruptions in the temporal organization of speech. In chronic stutterers, for example, gesture execution is paused during bouts of stuttered dysfluency. That is, if the hand had begun to rise in anticipation of gesture production, it was held in place until the end of the stuttered bout (Mayberry, Jaques, & DeDe, 2000).

There is also evidence to suggest that gesture and speech are tightly linked in children at the earliest stages of communication development. Between the ages of 9 and 12 months, most infants begin to produce communicative gestures (e.g., pointing, showing, requesting, waving "bye-bye;" Bates, 1976; Bates et al., 1979). For many children, the production of words is preceded by the appearance of first gestures, with the emergence of pointing serving as a particularly good predictor of first-word onset (Baldwin, 1991, 1993; Baldwin & Moses, 1996;

Bates et al., 1979; Caselli, 1990). Pointing onset and comprehension of object names have also been linked, with infants reportedly understanding their first categorical object name in the same week as they first produce the canonical point (Harris, Barlow-Brown, & Chasin, 1995). Similarly, pointing production is positively related to gains in language development between 9 and 13 months (Bates et al., 1979). One study showed that earlier age of onset of pointing was positively associated with word comprehension at 14 months (Butterworth & Morrissette, 1996). There are additional data demonstrating that the frequency of pointing at 12 months predicts speech production at 24 months (Camaioni, Caselli, Longobardi, & Volterra, 1991). Thus, gesture may serve a facilitating role in the achievement of first words.

Just as gesture appears to ease the child into the production of first words, it also plays a role in the transition from one- to two-word speech. Shortly before the emergence of two-word combinations, children begin to combine single gestures with single words (e.g., pointing at a cup while saying "mommy"). These gesture-word combinations generally appear between the ages of 14 and 16 months (e.g., Bates et al., 1979; Goldin-Meadow & Morford, 1985). Research suggests that two-word utterances begin to emerge only after children have begun producing gesture-word combinations, and that a particular type of gesture-word combinations--one in which the gesture conveys different, but related information from the spoken word (i.e., supplementary gesture-word combinations)--may be a particularly salient indicator of the imminence of the transition to two-word speech (Butcher & Goldin-Meadow, 2000; Capirci, Iverson, Pizzuto, & Volterra, 1996; Goldin-Meadow & Morford, 1985; Morford & Goldin-Meadow, 1992). For example, Iverson and Goldin-Meadow (2005) found a significant positive correlation between age of onset of supplementary gesture-word combinations and age of onset of two-word combinations. Thus, the relationship between gesture and speech within a single communicative message appears to herald change in the child's linguistic system. Consequently, the gesture-speech link may serve as an index of a child's transitional status in language development.

It has been noted that the gesture-speech system also undergoes a reorganization in temporal sequencing and specific patterning of expressive behaviors (Butcher & Goldin-Meadow, 2000). Gesture's relationship to speech is modified with respect to infants' ability to coordinate these two behavioral modalities in time. Around the time of the second birthday, synchrony between speech and gesture begins to resemble the adult pattern, in which the gesture movement (the stroke) is executed as the co-expressive word or phrase is verbally expressed (McNeill, 1992). Butcher and Goldin-Meadow (2000) have shown that the adult pattern of gesture-speech synchrony is evident by the time children make the transition to two-word utterances. Specifically, once gesture became appropriately timed with respect to speech, children began combining gestures with meaningful words. Theirs is the only known study that investigated the temporal sequencing of gesture and speech in young children.

In sum, the evidence on the development of gesture and speech establishes a firm relationship between these communicative modalities and suggests the existence of an integrated gesture-speech system. This evidence further exemplifies the tendency for well-established modalities of expression to continue to play a role in communication during a time when new skills are emerging. Thus, gesture does not disappear once more "effective" means of communication emerge; rather, it continues to play a role in the emergence of language. There is also some suggestion that gesture facilitates the development of language and may play a supportive role in linguistic transitions.

1.6 THE PRESENT STUDY

The literature reviewed above underscores the importance of considering the gestural, vocal, and affective modalities comprehensively. An examination of the interplay between these modalities and the ways in which their relationships change over time, particularly during periods of developmental transition, is clearly warranted. Moreover, prior work suggests that there is reason to expect differing relationships between language and other components of the communicative system. In light of evidence that has established links between affect and language and, separately, gesture and language, one might expect advances in language to impact these links in different ways. There is also reason to believe that variation in the rate of linguistic acquisition during the vocabulary spurt may translate into individual differences in the way in which the vocabulary spurt impacts the communicative system.

The present study was designed to investigate the reorganization of communicative behaviors during the window of time surrounding the vocabulary spurt, a major linguistic transition, by considering the interplay between affect, gesture, and language as the system moves from a period of stability to instability. This research offers a unique approach to studying early communication development, one that considers the dynamics of change and the variability and instability that arise during a period of developmental transition. Ultimately, this study asks how the closely linked relationship between gesture, affect, and speech is altered as the linguistic system undergoes a period of significant growth.

This study will extend previous research in several ways. First, although many researchers have described the vocabulary spurt as a discrete developmental transition, none has explored the impact of this achievement on the communicative system as a whole. Further, most studies of communication have examined one or two expressive modalities at once, but there has not yet been a study that considers the influence and temporal organization of multiple means of communicative expression. Additionally, although individual differences in the way children experience the vocabulary spurt have been documented, little research has examined this variability in specific ways. Finally, a milestone-based investigation offers a distinct perspective as it permits an examination of changes in behaviors as they specifically relate to the emergence of a new communicative skill.

The specific aims of the proposed research are: a) to investigate the production and coupling of affective expressions, gestures, vocalizations, words, and the temporal organization of their respective coordinations at the time surrounding the vocabulary spurt; b) to test general principles of dynamic systems theory by describing the extent to which instability impacts the overall production of coordinations between expressive behaviors and the integration of newly emerging behaviors; and c) to investigate the way in which individual differences in the vocabulary spurt may relate to changes in communication patterns. This study will provide detailed information regarding the patterning and coordination of different expressive actions as they unfold in relation to one another in real time during a well-characterized period of systemic instability. Based on the evidence reviewed above, the following predictions have been generated.

1. As previously discussed, the vocabulary spurt is a transitional period characterized by instability and variability. Accordingly, the dynamic systems notion of soft-assembly suggests that behavioral components are more susceptible to decoupling during points of marked instability. Thus, it is predicted that the session coinciding with onset of the vocabulary spurt will differ from surrounding sessions with respect to the frequency of coordinated expressions. In other words, it is expected that fewer communicative acts occurring in coordination would be

observed at the vocabulary spurt session as opposed to the pre- and post-vocabulary spurt sessions.

2. An important manifestation of the close relationships between affect, gesture, and speech is the relative degree of temporal coordination between expressive behaviors. A dynamic systems view suggests that the multiple interacting components in a system assemble and reassemble during times of transition. As new behavioral forms are practiced and increasingly integrated with other, more established expressions, the stability of the communicative system may be indexed by the degree to which behaviors are sequentially organized. Therefore, it is expected that there will be marked differences in the temporal sequence of expressive behaviors after the onset of the vocabulary spurt. These differences may be manifested in three distinct ways. First, it is predicted that there will be a greater number of temporally asynchronous utterances at the time of the vocabulary spurt, so that gestural or affective displays will rarely occur simultaneously with speech. Second, differences are predicted in the initiating behavior of a coordinated bout, in that there will be an increase in the likelihood of *meaningful* vocalizations initiating communicative utterances between the vocabulary spurt and post-spurt sessions. Finally, it is expected that as children gain more experience in coordinating communicative behaviors, the duration of coordinated bouts will become briefer.

3. At the time of the vocabulary spurt, speech is a newly emerging communicative behavior, and accordingly a relatively unstable component in the communicative system. Based on a dynamic systems view presented by Iverson and Thelen (1999), the relative instability of language decreases the likelihood of its co-occurrence with other expressive behaviors. Thus, it is predicted that meaningful vocalizations produced by infants at the vocabulary spurt session will be especially likely to occur in isolation. It is also anticipated that at times of relative

stability (i.e., the pre-spurt and post-spurt sessions), meaningful vocalizations will be observed to accompany other communicative expressions (e.g., gestures and facial affect) in a single utterance.

The notion that newly emerging behavioral forms are particularly vulnerable to disruption should apply not only to speech in general, but also to specific lexical items. Accordingly, it is proposed that the amount of practice children have with specific words will influence the likelihood that those words will be combined with other communicative expression. Thus, words that are less practiced (newly acquired) will tend occur in isolation, and those that have a longer history in the child's vocabulary will be more likely to be combined with gestures and/or affective expressions.

4. Dynamic systems theory also asserts that older behavioral forms (i.e., those that are well-practiced and more established) are less susceptible to disruption and should be particularly prominent during periods of significant change and instability. Therefore, it is predicted that the coupling of older forms of communication (e.g., affective expressions, gestures) will be less effortful and that these types of coordinations will occur more often at the vocabulary spurt session as compared to surrounding sessions.

5. The literature suggests that component parts of the communicative system have different relationships with language. Thus, there may be differences in the extent to which gesture and facial affect are coordinated with meaningful vocalizations. Gesture has been suggested to facilitate language learning with evidence indicating that the relationship between gesture and speech predicts the onset of communicative transitions (e.g., Bates, 1976; Butcher & Goldin-Meadow, 2000; Camaioni et al., 1991; Iverson & Goldin-Meadow, 2005). By contrast, in Bloom's view, affect has an inhibitory effect on the achievement of linguistic milestones

(Bloom, Beckwith, & Capatides, 1987; Bloom & Capatides, 1987). Therefore, it is expected that words will appear in coordination with gestures more often than they will appear in coordination with affect, particularly at the spurt session.

In addition to the predictions detailed above, a further aim of this study is to examine individual differences in the onset of the vocabulary spurt. Ganger and Brent (2004) were among the first to make a distinction between children who qualify for a vocabulary spurt by crossing a loosely defined threshold and those who qualify with the identification of an inflection point (see also van Geert, 1991). This particular distinction may be an important factor in understanding and explaining the large amount of variability observed in other studies of vocabulary acquisition (Dale & Goodman, 2005; Gershkoff-Stowe, 2001, 2002; Goldfield & Reznick, 1990). This logic, when applied to the current study, suggests that children whose vocabulary growth consists of a discrete transition between a slow word learning rate and a faster word learning rate (marked by an inflection point) may show evidence of greater system-wide instability than children whose vocabulary growth shows continuous incremental improvement. More specifically, it is predicted that differences between groups are most likely to exist in the frequency with which children coordinate communicative expressions in general and newly emerging behaviors (i.e., speech) in particular.

2.0 METHOD

2.1 PARTICIPANTS

Participants included a subset of 30 typically developing, healthy infants (14 males and 16 females), and their primary caregivers recruited as part of a larger, long-term longitudinal study of infant vocal-motor coordination funded by the National Institute of Health (NIH). Dyads were recruited from two separate sites, a small Midwestern city and a large mid-Atlantic city, through local newspaper birth announcements and word of mouth. Eligible families were contacted by an introductory letter and follow-up phone call. All infant participants were full-term, from uncomplicated pregnancies and deliveries, had 5-minute neonatal Apgar scores within the normal range (9 or better; Apgar, 1953), and came from monolingual, English-speaking homes. Twelve of the infants were first born and 18 had at least one older sibling. The majority of the participants were Caucasian (28 infants) while the remaining two were Asian-American. Approximately 93% of mothers and fathers of participating infants had some college, a college degree, or some graduate or professional school experience. Of the 30 participating dyads, 20 were selected for observation in the present study. Dyads were selected for inclusion if the infant achieved an observable vocabulary spurt before the completion of the longitudinal study (see section below for vocabulary spurt identification procedure).[1] Two infants were excluded from the study due to sickness and/or data collection error (e.g., malfunction in sound equipment).The final sample of 18 infants was approximately 39% male (7 infants) and 95% Caucasian (17 infants). Seven of the infants were first born. Approximately 55% of mothers of infants in this sample had some post-graduate training and approximately 45% had some college or a college degree. For fathers, approximately 39% had some graduate or professional school experience, 45% had some college or a college degree, and approximately 11% had only completed high school.

Infants were followed bi-monthly from 2 to 19 months of age. One visit was conducted to coincide with the monthly anniversary of the infant's birthday, and the second monthly visit was scheduled for the midpoint between birthday anniversaries. In an effort to ensure continued participation, families were compensated $25.00 for each observation session. For the present study, we selected three sessions from the period in which infants achieved the vocabulary spurt (see below).

2.2 PROCEDURE

Infants were observed at home with a primary caregiver. Observations were scheduled for a time during the day when infants were expected to be alert and playful. Every effort was made to schedule home visits within two days of the targeted observation date. Scheduled observations that were missed due to illness or family obligations were rescheduled at the earliest possible opportunity.

2.3 MEASURES

At each session, parents were asked to complete the MacArthur-Bates Communicative Development Inventory (CDI; Fenson et al., 1993). The CDI is a widely used measure with excellent internal consistency and test-retest reliability, as well as concurrent validity with tester-administered measures (Fenson et al., 1994). The Words and Gestures Form of the CDI is for use with children between the ages of 8 and 16 months and is organized into two parts. Part I consists of a 396-item vocabulary checklist that asks parents to check items that their child only understands and those that s/he both says and understands. Part II of the Words and Gestures Form focuses on early gestures (e.g., giving, showing, pointing) and actions (e.g., games and routines, pretend play), and parents are requested to indicate those performed by their child. Beginning when infants were 16 months old, the Words and Sentences Form of the CDI was administered to parents. This form is designed for use with children 16 to 30 months of age and consists of two parts. Part I is a 680-word vocabulary checklist organized into 22 semantic categories that asks parents to indicate words that their child says. The second section consists of questions relating to children's use of English morphology and syntax.

2.4 VIDEOTAPED OBSERVATIONS

Infants were videotaped for approximately 45 minutes in two major settings: while engaged in everyday household activities and routines, and during a semi-structured toy play session. To enhance the audio component of the recordings, infants wore a small wireless microphone clipped to a cloth vest worn over their clothing during the session.

The first and final 15-minute segments consisted of unstructured, naturalistic observation. Caregivers were asked to continue their normal activities during this time; no attempt was made to structure this portion of the session in any way. During the middle 15-minute segment, infants and primary caregivers participated in a semi-structured play session involving play with toys and social interaction. In this portion of the session, caregivers were seated on the floor with the infant, and infants were videotaped while playing with the caregiver and some favorite toys. The same fixed order of observational contexts was employed for all infants at all sessions.

For the purposes of this study, the middle semi-structured play and the final naturalistic play periods were selected for analysis, resulting in a total observation period of 30 minutes, generally beginning 15 minutes into the visit and extending to the 45 minute mark.[2]

2.5 IDENTIFYING THE VOCABULARY SPURT

The milestone-driven approach employed in the present study involved the use of data from sessions selected relative to milestone achievement. Data from three observations were included for each infant participant: 1) the visit occurring one month prior to the onset of the vocabulary spurt; 2) the visit coinciding with the onset of the vocabulary spurt; and 3) the visit occurring one month following the onset of the vocabulary spurt. The age at which infants achieved the vocabulary spurt was determined using data from the CDI. The total expressive language score (i.e., those items that the child both understands and says from Part I of the Words and Gestures form, and those items marked in Part I of the Words and Sentences form) was computed for each session. The vocabulary spurt session was identified as the first session at which the number of words produced by the infant increased by at least 10 in a given 2-week period, after the infant had acquired at least 20 different words (i.e., threshold approach; Bloom & Capatides, 1987; Ganger & Brent, 2004; Goldfield & Reznick, 1990; Gopnik & Meltzoff, 1987; Lifter & Bloom, 1989; Mervis & Bertrand, 1994, 1995; Reznick & Goldfield, 1992; see Figure 2 for an example). The mean age at vocabulary spurt was 16.21 months (range = 14 to 18 months). Data from seven infants were examined for a vocabulary spurt but did not meet the established criteria. Although 4 of the 7 infants met the criterion base of 20 expressive words, there was no observed increase of 10 words in a 2-week period (nor was there an increase of 10 words in a 4-week time period). The remaining 3 infants did not produce 20 words by the end of the data collection period.

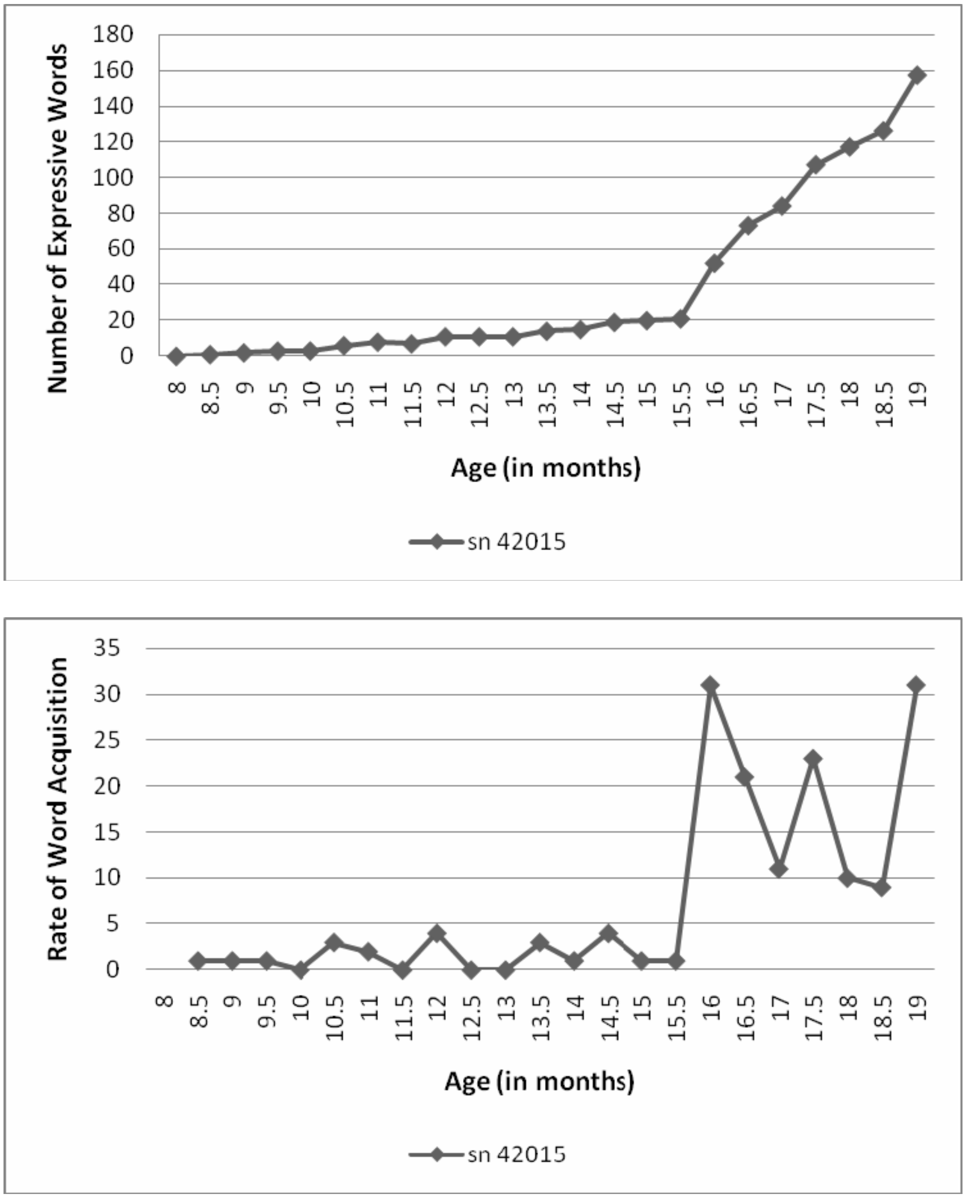

Figure 2 Prototypic example of the vocabulary spurt as defined by an increase of 10 words in two weeks after having had achieved a base of 20 expressive words.

2.6 CODING

Coding was completed by one primary observer (the first author) and three secondary observers, who were blind to the study's hypotheses. All gestures, facial affective expressions, and vocal utterances (i.e., meaningful and nonmeaningful vocalizations), produced by infants during the 30-minute session were identified and coded for onset and offset. A manual for coding infants' communicative expressions was created based on coding schemes developed for the speech and gestures of very young children (e.g., Iverson & Goldin-Meadow, 2005), and for infant facial expressions (babyFACS; Oster, 2000). The criteria used in coding each of these categories of behavior are described below (see Table 1; for further details, see the coding manual included in the Appendix). To permit detailed analyses of the relative timing of communicative behaviors, videotape coding was completed using a time-linked, computer-based video interface system (The Observer Video-Pro, Noldus Information Technologies). Only those expressive behaviors deemed to be truly spontaneous communication bids on the part of the infant were coded. Episodes in which the caregivers' speech or movement may have elicited the infant's communicative bid were not coded.

2.6.1 Gestures

Several criteria were instituted to ensure that a hand movement qualified as a gesture (see Butcher, Mylander, & Goldin-Meadow, 1991; Goldin-Meadow & Mylander, 1984): 1) The gesture must have been directed to another individual. In particular, the child must have established eye contact or given other evidence of trying to attract the attention of the communicative partner for the action to have been considered a gesture; 2) The gesture itself must not have been a direct manipulation of some relevant person or object (i.e., it must have been empty-handed; Petitto, 1988). There were two exceptions—if a child held up an object to bring it to another's attention (i.e., showing), or if the child handed over an object to another in an act of sharing/offering or requesting (i.e., giving); 3) The gesture must not have been part of a ritual act (e.g., blowing a kiss to someone) or game (e.g., patty cake).

All gestures were classified into two main categories: *deictic* and *representational*. *Deictic* gestures are signals that express the child's communicative intent to request or declare. These types of gestures indicate referents (i.e., object, location, or event) in the immediate environment, and their meanings are thus context-bound. Deictic gestures were coded as *Point*, *Reach*, *Give*, or *Show*. *Pointing* was coded when the child used an extended index finger to indicate his/her interest in or desire for an object or event. *Reaching* was coded when the child extended his/her arm toward an out of reach object. *Gives* were coded when the child pushed, threw, or handed an object to the caregiver or experimenter in order to share, request help with, or get rid of an object. *Shows* were coded when the child raised a toy or object upward toward the adult's face while making eye contact.

Representational gestures refer to an object, person, location, or event through hand movement, body movement, or facial expression. These gestures differ from deictic gestures in that they represent specific referents and their basic semantic content does not vary with the context. Representational gestures were classified as *conventional*, *predicate*, or *nominal gestures*. *Conventional* gestures have a form and meaning that are either culturally defined (e.g., nodding the head "yes") or one specified in the context of a particular caregiver-child interaction (e.g., putting hands up in the air spaced far apart for "big"). *Predicate* gestures describe qualities or characteristics of an object or situation (e.g., waving hands for "hot"). *Nominal* gestures provide a label for a specific object. They can act as labels by either: a) replicating the action performed by an agent involving the object (e.g., shaping the hand like a cup and pretending to drink for “cup”), or b) copying the movement that would be performed by the object itself (e.g., flapping arms for “bird”).

2.6.2 Vocal Utterances

All meaningful and nonmeaningful communicative vocalizations were coded. The general criterion that was used to identify meaningful vocalizations was the use of the same sound pattern to refer to a specific referent on multiple occasions or in different contexts. Meaningful vocalizations (hereafter termed “words”) were either actual English words (e.g., “dog,” “cat,” “duck,” “hot”) or speech sounds that were consistently used by a particular child to refer to a specific object or event (e.g., using “bah” to refer to a bottle in a variety of different contexts. Words that were purely imitative (i.e., words repeated immediately after being spoken by another person) were not coded.

For nonmeaningful vocalizations (hereafter termed “vocalizations”), all infant sound productions, with the exception of sneezing, coughing, breathing, and other vegetative noises, were coded. Vocalization codes included instances of vowel strings, reduplicated babbling, or variegated babbling. Affective vocalizations such as laughing, squealing, fussing, and crying were coded separately and subsequently removed from all analyses. The temporal duration of all verbal utterances was also determined.

2.6.3 Facial Affect Expressions

Facial expressions were coded as *Positive Emotionality/Joy*, *Negative Emotionality/Distress*, or *Surprise/Interest*, and the onset and offset times for each expression was recorded. *Positive* *emotionality/joy* was defined as the presence of upward lip corner pull (AU12) and/or cheek raising (AU26c-e/27). *Negative emotionality/distress* was defined by the presence of downward lip corner pull (AU12) and brows lowered/furrowed and/or mouth opening and/or cheek raising. *Surprise/interest* was defined as the presence of one or any combination of the following three action units: raised brows, raised eyelids, or mouth opening (Ekman & Friesen, 1978; Facial Action Coding System, FACS).

Table 1 Summary of Coding Criteria used in the Present Study

Behaviors Coded	Description	Examples	Reliability
Vocal Utterances			92% ID Agreement
Words	Use of the same sound pattern to refer to a specific referent on multiple occasions or in different contexts[a]	"Bye-bye" or "da" for dog	87% Type Agreement
Vocalizations	All other sound productions except affective vocalizations (e.g., crying) and vegetative noises (e.g., sneezing; coughing)	Vowel strings; babbling	0.69 Cohen's Kappa
Gestures	Must be directed to another person and not part of a ritual or game		89% ID Agreement
Deictic	Signals that express the child's communicative intent to request or declare	Reaching; showing	95% Type Agreement
Representational	Refer to an object, person, location, or event through hand or body movement	Nodding the head "yes"	0.94 Cohen's Kappa
Facial Affect	Classified using FACS coding system (Ekman & Friesen, 1978)		82% ID Agreement
Positive	Upward lip corner pull and/or cheek raising	Smiles;	
Negative	Downward lip corner pull and brows lowered/furrowed	Frowns	98% Type Agreement
Surprise	Raised brows, raised eyelids, or mouth opening		0.98 Cohen's Kappa

Note. Only those expressive behaviors deemed to be truly spontaneous communication bids on the part of the infant were coded.

[a]Words that were purely imitative (i.e., word produced immediately after being said by another person) were not coded.

2.6.4 Reliability

To assess inter-observer reliability, three secondary trained observers independently coded a sub-sample of approximately 10% (160 minutes) of the videotaped data (see Table 1). Average percentage agreement for identifying the occurrence of a vocal utterance, the occurrence of a gesture, and the occurrence of a facial affect expression was 92%, 89%, and 79%, respectively. Mean percentage agreement for classifying vocal utterance type, word type, gesture type, and affect type was 87%, 97%, 95%, and 98%, respectively. Cohen's kappa (Cohen, 1960) statistics were also calculated for classifying types of communicative behaviors within each category. The mean kappas for vocal utterance type, word type, gesture type, and affect type were, .69, .85, .94, and .98, respectively. Disagreements were resolved by joint viewing of the clips and discussion, and if a resolution was not reached, the first author decided on the appropriate code.

3.0 RESULTS

The present study was designed to explore the production of gestures, vocalizations, words, affective expressions, and the content and temporal organization of communicative coordinations at the time of the vocabulary spurt. Data from observations prior to, at, and following the onset of the vocabulary spurt were utilized without regard to infant age at the time of milestone achievement, and resulted in a dataset comprised of 54 datapoints (3 sessions for each of the 18 infants). Data were screened for outliers (i.e., values greater than two standard deviations above or below the mean), and these were replaced with a value one larger (or smaller) than the next most extreme score in the distribution (Tabachnick & Fidell, 1996). All proportional variables were arcsine transformed prior to conducting statistical analyses. One-way repeated measures analyses of variance (ANOVAs) with planned contrasts between adjacent ages were used to test several prediction-driven analyses examining changes from pre-spurt to spurt to post-spurt sessions. All analyses were carried out using version 14.0 of SPSS for Windows (SPSS, Inc., 2001).

We begin by presenting preliminary analyses focusing on potential gender, birth order, and age differences. Next, descriptive analyses regarding the nature of infants' communication patterns during the period surrounding the vocabulary spurt were conducted. Following these preliminary and descriptive analyses, data relevant to the five main study predictions are presented in turn. In a final section, we report analyses conducted to examine individual differences in the vocabulary spurt in relation to system-wide changes in communication.

3.1 PRELIMINARY ANALYSES

Potential effects of gender, birth order, and age were examined by analyzing the total number of communicative attempts (i.e., a behavior produced alone or a single coordinated bout). This measure was averaged across all three sessions to create a stable measure of infant communicativeness. An independent samples *t* test showed no effects of gender, $t(16) = -.307$, *ns*, or birth order, $t(16) = .242$, *ns*. Pearson's correlations revealed no association between infant age and communicativeness, $r = .365$, *ns*

3.2 DESCRIPTIVE ANALYSES

Three sets of descriptive analyses were conducted for this study. The first focused on change in infants' expressive vocabulary size during the vocabulary spurt. The second examined the frequency with which various communicative behaviors were produced, and the final set explored the composition of coordinated bouts of communicative behaviors.

The first set of analyses was carried out to verify the occurrence of the vocabulary spurt (determined from parental report data collected using the CDI) in the observational data. These analyses focused on the overall production of words (i.e., the mean number of meaningful vocalizations produced) and of new words (i.e., the mean number of meaningful vocalizations determined to be new to the child's vocabulary). With regard to production of words, a repeated measures ANOVA revealed a significant increase in the number of words produced over the three time points, $F(2, 34) = 12.73$, $p = .000$ ($M_{\text{pre-spurt}} = 15.28$, $SD = 11.72$; $M_{\text{spurt}} = 36.89$, $SD = 22.50$; $M_{\text{post-spurt}} = 44.78$, $SD = 22.69$), with planned contrasts indicating that the source of the effect was in the significantly higher number of words produced at the spurt relative to the pre-spurt session, $F(1, 17) = 14.90$, $p = .001$.

With regard to *new* words, a clear peak was apparent at the spurt session in particular ($M_{\text{pre-spurt}} = 3.78$, $SD = 7.17$; $M_{\text{spurt}} = 12.94$, $SD = 14.80$; $M_{\text{post-spurt}} = 6.28$, $SD = 5.88$). A repeated measures ANOVA confirmed this overall difference, $F(2, 34) = 4.05$, $p = .026$, and planned contrasts demonstrated a significant increase from the pre-spurt to the spurt session, $F(1, 17) = 4.98$, $p = .039$, and a marginally reliable drop from the spurt to the post-spurt session, $F(1, 17) = 4.17$, $p = .057$. Thus, the time points chosen as the vocabulary spurt for infants in this study based on information gathered from a parent report questionnaire (CDI) were consistent with observational data on infants' expressive vocabularies.

The second set of descriptive analyses focused on the types of communicative expressions produced by infants during the time surrounding the vocabulary spurt. Means and standard deviations for specific communicative behaviors are presented in Table 2. Inspection of the proportions of communicative behaviors produced indicated that the majority of expressions were vocalizations, a tendency that remained relatively stable over time ($M_{\text{pre-spurt}} = .60$, $SD = .12$; $M_{\text{spurt}} = .55$, $SD = .13$; $M_{\text{post-spurt}} = .54$, $SD = .12$). Words initially comprised 10% of all expressions produced, but this proportion almost doubled in size after the onset of the vocabulary spurt ($M_{\text{pre-spurt}} = .10$, $SD = .08$; $M_{\text{spurt}} = .18$, $SD = .08$; $M_{\text{post-spurt}} = .20$, $SD = .09$). Approximately 20% of all infant communications were gestures, a value that remained relatively stable over time ($M_{pre\text{-}spurt}$ = .20, SD = .08; M_{spurt} = .18, SD = .08; $M_{post\text{-}spurt}$ = .19, SD = .08). Facial affective expressions were least frequent; they appeared in less than 10% of all communications produced at the pre-spurt and spurt sessions and decreased slightly at the spurt session ($M_{pre\text{-}spurt}$ = .10, SD = .07; M_{spurt} = .10, SD = .05; $M_{post\text{-}spurt}$ = .07, SD = .04).

Table 2 Mean Number, Standard Deviation, and Range of Communicative Behaviors Produced at Each Time Point

	Observation								
	Pre-spurt			Spurt			Post-spurt		
Expressions	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*
Vocalizations	105.33	50.14	22-202	108.89	48.00	49-230	126.33	58.21	46-278
Words	15.28	11.72	2-43	36.89	22.50	7-77	44.78	22.69	7-98
New Words	3.78	7.17	0-22	12.94	14.80	0-55	6.28	5.88	0-17
Old Words	11.50	7.12	2-26	23.94	18.26	4-68	38.50	21.17	7-84
Gestures	33.00	18.60	9-85	32.61	15.96	13-63	42.89	20.20	11-78
Deictic	26.33	14.63	9-64	27.78	16.17	8-62	37.28	18.01	10-72
Representational	6.67	8.63	0-29	4.83	6.24	0-24	5.61	4.59	0-16
Facial Affect	14.22	9.08	2-36	17.61	7.77	1-32	14.50	6.31	3-24
Positive	12.50	8.51	2-31	16.78	7.65	1-30	13.89	6.94	0-24
Negative	1.00	2.03	0-8	0.33	0.59	0-2	0.39	0.70	0-2
Surprise	0.72	1.41	0-4	0.50	0.62	0-2	0.22	0.55	0-2

Note. n = 18; Data were collected from 30-minute observation sessions

The final set of descriptive analyses focused on the construction of coordinated bouts (i.e., communicative utterances in which two or more expressive behaviors overlapped in time) at the three observation points. Table 3a shows the mean proportions of coordinated bouts that involved gestures, vocalizations, words, or facial affect. As is apparent in the table, approximately 90% of all coordinated bouts involved a gestural expression ($M_{pre\text{-}spurt}$ = .90, *SD* = .11; M_{spurt} = .84, *SD* = .16; $M_{post\text{-}spurt}$ = .91, *SD* = .08). A repeated measures ANOVA indicated that gestures remained a particularly stable feature of coordinated bouts across the three time periods, $F(2, 34) = 1.16$, *ns*. Vocalizations were also frequently involved in coordinated bouts, but they appeared slightly less often at and following the onset of the vocabulary spurt ($M_{pre\text{-}spurt}$ = .81, *SD* = .18; M_{spurt} = .70, *SD* = .24; $M_{post\text{-}spurt}$ = .70, *SD* = .14), a trend that was marginally significant, $F(2, 34) = 3.21$, $p = .053$.

At the pre-spurt session, both words and facial affect expressions occurred in bouts with similar frequency (i.e., approximately 15%). However, the proportion of bouts including words increased across all sessions, $F(2, 34) = 6.52$, $p = .004$ ($M_{pre\text{-}spurt}$ = .15, *SD* = .14; M_{spurt} = .20, *SD* = .15; $M_{post\text{-}spurt}$ = .31, *SD* = .14), with planned contrasts indicating significant change from the spurt to the post-spurt session, $F(1, 17) = 6.07$, $p = .025$. In contrast, the proportion of bouts involving facial affect peaked at the vocabulary spurt session and then declined, $F(2, 34) = 4.09$, $p = .026$ ($M_{pre\text{-}spurt}$ = .15, *SD* = .11; M_{spurt} = .29, *SD* = .19; $M_{post\text{-}spurt}$ = .17, *SD* = .14). Planned contrasts revealed a significant increase from the pre-spurt to the spurt session, $F(1, 17) = 6.42$, $p = .021$, and a trend toward significance from the spurt to the post-spurt session, $F(1, 17) = 3.58$, $p = .076$.

Table 3a Mean Proportion of All Coordinated Bouts Involving Gestures, Vocalizations, Words, and Facial Affect

	Observation								
	Pre-spurt			Spurt			Post-spurt		
Behaviors	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*
Gestures	0.90	0.11	0.67-1.00	0.84	0.16	0.55-1.00	0.91	0.08	0.78-1.00
Vocalizations	0.81	0.18	0.28-1.00	0.70	0.24	0.14-1.00	0.70	0.14	0.37-1.00
Words	0.15	0.14	0.00-0.41	0.20	0.15	0.00-0.43	0.31	0.14	0.17-0.55
Facial Affect	0.15	0.11	0.00-0.33	0.29	0.19	0.00-0.57	0.17	0.14	0.00-0.48

Note. n = 18; Data were collected from 30-minute observation sessions

In sum, infants acquired and produced words during the period of observation, with a strong peak in the number of new words coinciding with the onset of the vocabulary spurt. Furthermore, words appeared to be increasingly integrated into bouts of communicative coordination. However, speech was not the only method of communication observed during this time period. Overall, gestures remained a prominent form of communication around the time of the vocabulary spurt and were the most frequently appearing behaviors in coordinated bouts. Moreover, infants continued to utilize developmentally earlier forms of communication such as vocalizations and facial affect expressions; however, the degree to which these behaviors appeared in coordinated bouts decreased after the onset of the spurt.

3.3 PREDICTION-DRIVEN ANALYSES

In this section, we focus on the five predictions derived from dynamic systems theory regarding ways in which the production of communicative behaviors may be impacted by the vocabulary spurt. Data relevant to each prediction will be presented in turn.

3.3.1 Coordination of communicative behaviors will be less likely to occur during the vocabulary spurt session in comparison to the pre-spurt and post-spurt sessions.

Coordination of communicative behaviors will be less likely to occur during the vocabulary spurt session in comparison to the pre-spurt and post-spurt sessions. The first prediction was that the coordination of communicative behaviors would be disrupted during a time of systemic instability (i.e., the vocabulary spurt). Descriptive statistics for coordinated bouts are presented in

Table 3b. All of the infants produced multiple coordinated bouts at each session. Because the opportunity to produce coordinated bouts was held constant (i.e., all infants were observed for 30 minutes at each time point), this prediction was first examined by comparing the total number of coordinated bouts across sessions. A repeated-measures ANOVA revealed significant change over sessions, $F(2, 34) = 5.94$, $p = .006$ ($M_{pre\text{-}spurt} = 19.44$, $SD = 11.17$; $M_{spurt} = 19.22$, $SD = 9.55$; $M_{post\text{-}spurt} = 29.22$, $SD = 14.12$). Planned contrasts indicated no significant difference in number of communicative coordinations between the pre-spurt and spurt sessions, $F(1, 17) = .01$, $p = .946$; however, coordinations increased significantly from the spurt to the post-spurt session, $F(1, 17) = 11.91$, $p = .003$. Although the frequency with which infants produced coordinated bouts increased after the onset of the vocabulary spurt, the average number of communicative behaviors involved in coordinated bouts remained relatively unchanged across the three sessions, $F(2, 34) = 1.35$, $p = .274$ ($M_{pre\text{-}spurt} = 2.04$, $SD = .08$; $M_{spurt} = 2.04$, $SD = .06$; $M_{post\text{-}spurt} = 2.07$, $SD = .09$).

To examine potential developmental change in frequency of coordination relative to overall production of communicative expressions (i.e., the number of coordinated bouts divided by the total number of communicative attempts), data were subjected to a repeated measures ANOVA with planned contrasts. Although the mean proportion of communications that were coordinated bouts was lower at the spurt session compared to the surrounding sessions, the difference was not statistically reliable, $F(2, 34) = 1.73$, $p = .193$ ($M_{pre\text{-}spurt} = .14$, $SD = .07$; $M_{spurt} = .11$, $SD = .06$; $M_{post\text{-}spurt} = .15$, $SD = .06$).

Table 3b Descriptive Information for Coordinated Bouts: Mean Number, Proportion, and Duration of Bouts, and Number of Behaviors Involved in Bouts

	Observation								
	Pre-spurt			Spurt			Post-spurt		
Measure	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*
Number of Bouts	19.67	11.50	5.00-47.00	19.22	9.55	7.00-35.00	29.22	14.11	5.00-63.00
Proportion of Bouts[a]	0.14	0.07	0.03-0.28	0.11	0.06	0.04-0.23	0.15	0.06	0.05-0.27
Duration of Bouts	3.24	0.96	1.64-4.93	2.69	0.54	1.87-3.53	2.37	0.48	1.64-3.21
Number of Behaviors[b]	2.04	0.08	1.99-2.23	2.04	0.06	1.97-2.15	2.07	0.09	2.00-2.31

Note. n = 18; Data were collected from 30-minute observation sessions

[a]Mean proportion of all communicative attempts that were coordinated bouts

[b]Mean number of communicative behaviors involved in coordinated bouts

3.3.2 Changes in temporal coordination will be particularly evident at the vocabulary spurt session

Changes in temporal coordination will be particularly evident at the vocabulary spurt session. As previously discussed, a dynamic systems view suggests that the multiple interacting components in a developing system dissemble and reassemble during times of transition. Therefore, it was expected that there would be changes in the temporal sequencing of coordinated expressive behaviors during the vocabulary spurt. These differences are likely to be manifested in three ways. First, synchrony among communicative behaviors (e.g., infant begins to point and vocalizes at the same time) may index the relative stability of the system so that during a time of marked change, synchrony should be disrupted. Second, a communicative behavior that is particularly new or unstable (e.g., words, and especially new words) may be less likely to initiate a coordinated bout than an older, more well-established behavior (e.g., gesture). Finally, as infants gain experience in sequencing and integrating behavioral forms, it is expected that coordinated bouts will become briefer in duration.

To address the prediction that synchrony among communicative behaviors would be less common at the vocabulary spurt and improve as the system regains stability, all coordinated bouts were classified according to whether they were synchronous (i.e., the first communicative behavior was produced within .3 seconds of the second) or asynchronous. As expected, there was a tendency for the mean proportion of synchronous coordinated bouts to increase after the vocabulary spurt session, a trend that approached significance, $F(2, 34) = 3.07$, $p = .060$ ($M_{\text{pre-spurt}} = .42$, $SD = .15$; $M_{\text{spurt}} = .46$, $SD = .16$; $M_{\text{post-spurt}} = .53$, $SD = .11$).

It was also anticipated that older, more stable behaviors would be more likely to initiate a communicative interaction than newly emerging behaviors. To assess this prediction, we examined asynchronous bouts in order to identify the communicative behavior that initiated the bout and classified them according to the initiating behavior (e.g., word, vocalization, gesture, facial affect expression). Data indicated that, as predicted, the majority of asynchronous bouts were initiated by a gesture ($M_{\text{pre-spurt}} = .68$, $SD = .21$; $M_{\text{spurt}} = .65$, $SD = .23$; $M_{\text{post-spurt}} = .59$, $SD = .20$) while words were least likely to initiate asynchronous bouts ($M_{\text{pre-spurt}} = .02$, $SD = .05$; $M_{\text{spurt}} = .06$, $SD = .08$; $M_{\text{post-spurt}} = .11$, $SD = .13$). Vocalizations ($M_{\text{pre-spurt}} = .14$, $SD = .15$; $M_{\text{spurt}} = .11$, $SD = .11$; $M_{\text{post-spurt}} = .15$, $SD = .13$) and facial affect ($M_{\text{pre-spurt}} = .14$, $SD = .12$; $M_{\text{spurt}} = .16$, $SD = .18$; $M_{\text{post-spurt}} = .13$, $SD = .15$) were also fairly unlikely to initiate asynchronous bouts.

As words are increasingly practiced and integrated into communicative bouts, however, they should become increasingly likely to appear as the initiating behavior. Thus, it was expected that words would be more likely to initiate coordinated bouts *after* the onset of the vocabulary spurt. Although the overall main effect was significant, $F(2, 34) = 3.62$, $p = .038$ (see above for means), planned contrasts did not detect significant change from the pre-spurt to the spurt session or from the spurt to the post-spurt session, *ns*. Further analyses indicated the source of the main effect was in the significant difference between the pre-spurt and post-spurt sessions, $F(1, 17) = 5.93$, $p = .026$ There were no significant changes in the proportion of bouts initiated by a vocalization, gesture, or facial affect expression across time points, *ns*.

Finally, it was expected that the total duration of coordinated bouts (i.e., the onset of the first behavior subtracted from the offset of the last behavior) would decrease as infants gain experience combining communicative behaviors. A repeated measures ANOVA revealed that, as predicted, the mean duration of coordinated bouts became briefer over time ($M_{\text{pre-spurt}} = 3.24$, *SD*

= .96; M_{spurt} = 2.69, *SD* = .54; $M_{post\text{-}spurt}$ = 2.37, *SD* = .48), *F*(2, 34) = 9.68, *p* = .000. There was a significant decrease from the pre-spurt to the spurt session, *F*(1, 17) = 9.38. *p* = .007, and a marginally significant decrease from the spurt to the post-spurt session, *F*(1, 17) = 3.48, *p* = .079.

3.3.3 Less practiced communicative behaviors (i.e., words, and particularly new words) are especially effortful and thus should be more likely to appear alone and less likely to appear in coordinated bouts

Less practiced communicative behaviors (i.e., words, and particularly new words) are especially effortful and thus should be more likely to appear alone and less likely to appear in coordinated bouts. We addressed the prediction that newly emerging behaviors would be more likely to be produced in isolation in two ways. First, we examined the frequency with which words occurred in isolation in general. We then looked specifically at new words (i.e., words that have been a part of the infants' vocabularies for less than one month) to assess whether they would be less likely to appear in coordination with other communicative behaviors than old words.

To examine the prediction that words in general would be more likely to be produced in isolation at the spurt session relative to the pre-spurt and post-spurt sessions, the proportion of words produced alone (i.e, number of words not involved in coordinated bouts divided by the total number of words produced) was analyzed across sessions. Although the mean proportion of words produced alone increased from the pre-spurt to the spurt session and decreased from the spurt to the post-spurt session as expected, the differences were not statistically reliable, *F* (2, 34) = 2.81, *p* = .074 ($M_{pre\text{-}spurt}$ = .78, *SD* = .19; M_{spurt} = .87, *SD* = .13; $M_{post\text{-}spurt}$ = .80, *SD* = .11).

The second set of analyses involved examination of children's productive vocabularies for the history of specific words to determine whether nascent communicative behaviors such as *new* words would be impacted by the onset of the vocabulary spurt. Specifically, during the time surrounding the vocabulary spurt, new words are particularly effortful; and if they are produced, they should be less likely to appear in coordination with other behaviors. To address this prediction, all words produced within a session were classified as new or old. To qualify as a new word, a given word must have been a new addition to the CDI at that session.

Although the mean proportion of words produced that were new more than doubled at the vocabulary spurt session ($M_{\text{pre-spurt}}$ = .15, *SD* = .19, M_{spurt} = .32, *SD* = .28; $M_{\text{post-spurt}}$ = .14, *SD* = .14), overall new words were much less likely to be produced than words that had been a part of infants' vocabulary for more than one month. Moreover, consistent with expectation, when new words occurred, they were most often produced in isolation ($M_{\text{pre-spurt}}$ = .93, *SD* = .14, M_{spurt} = .87, *SD* = .17; $M_{\text{post-spurt}}$ = .78, *SD* = .21).

We next compared the proportions of coordinated bouts containing new vs. old words to examine the relative likelihood with which new versus old words appeared in coordinated bouts. These data are presented in Figure 3. As predicted, paired samples *t* tests revealed that the mean proportion of bouts involving new words was significantly different from the mean proportion of bouts involving old words at the spurt session, $t(17) = -2.35$, $p = .031$ (M_{new} = .06, *SD* = .08; M_{old} = .13, *SD* = .12), and the post-spurt session, $t(17) = -5.31$, $p = .000$ (M_{new} = .04, *SD* = .04; M_{old} = .26, *SD* = .15), with no reliable difference at the pre-spurt session, *ns* (M_{new} = .04, *SD* = .09; M_{old} = .08, *SD* = .08).

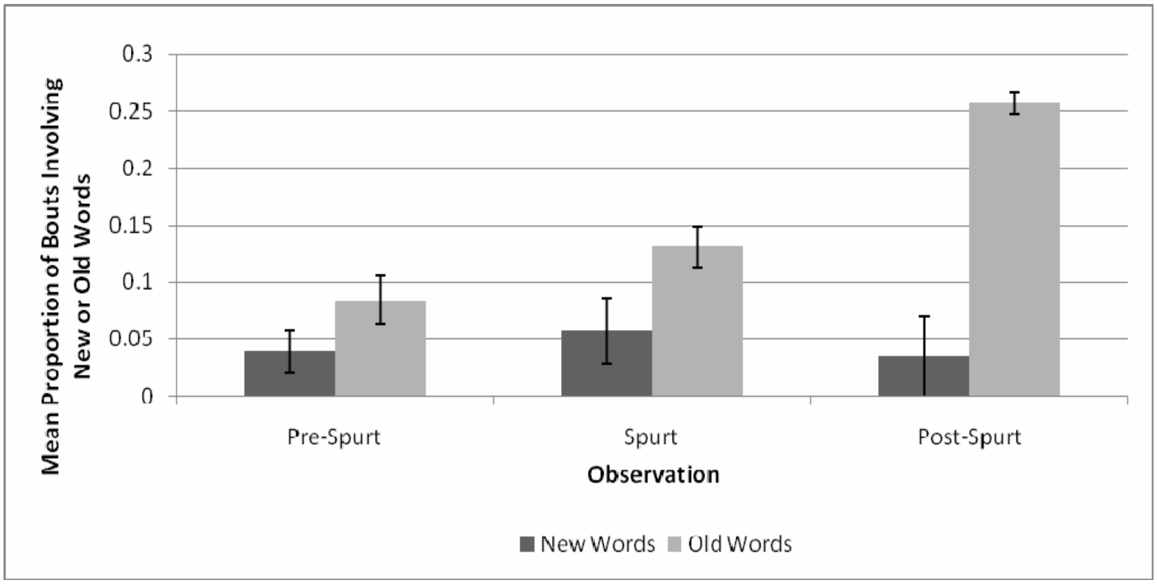

Figure 3 Mean proportion of coordinated bouts involving new or old words

3.3.4 Well-established communicative behaviors (e.g., gestures and facial affect) are less effortful and thus should occur more often at the vocabulary spurt session

Well-established communicative behaviors (e.g., gestures and facial affect) are less effortful and thus should occur more often at the vocabulary spurt session. To address the prediction that more established forms of communication would be more prominent during a time of instability, we examined the specific types of coordinated bouts produced by infants across sessions to identify those that involved more well-established forms of communicative expressions. More specifically, the mean proportions of coordinated bouts consisting of gesture + facial affect, facial affect + vocalization, and gesture + vocalization were compared across sessions. Inspection of the data revealed that coordinated bouts comprised of gesture + facial affect occurred more often at the vocabulary spurt than at surrounding sessions, $F(2, 34) = 5.30$, $p = .010$ ($M_{\text{pre-spurt}} = .04$, $SD = .06$, $M_{\text{spurt}} = .09$, $SD = .09$; $M_{\text{post-spurt}} = .02$, $SD = .04$). As expected, there was a significant increase from the pre-spurt session to the spurt session, $F(1, 17) = 6.05$, p

= .025, and a significant decrease from the spurt session to the post-spurt session, $F(1, 17) = 6.90$, $p = .018$.

Moreover, there was a marginally reliable tendency for coordinated bouts comprised of facial affect + vocalization to peak at the vocabulary spurt session, $F(2, 34) = 3.06$, $p = .060$ ($M_{\text{pre-spurt}} = .07$, $SD = .08$, $M_{\text{spurt}} = .14$, $SD = .15$; $M_{\text{post-spurt}} = .07$, $SD = .07$). Also consistent with expectation, the most common type of coordinated bout at the spurt session was gesture + vocalization. However, there was an overall decrease in coordinated bouts comprised of gesture + vocalization, $F(2, 34) = 4.99$, $p = .013$, with planned contrasts indicating that the source of the effect was in the decline from the pre-spurt session to the spurt session, $F(1, 17) = 9.20$, $p = .008$ ($M_{\text{pre-spurt}} = .68$, $SD = .20$, $M_{\text{spurt}} = .51$, $SD = .21$; $M_{\text{post-spurt}} = .57$, $SD = .14$).

3.3.5 Gestures and facial affective expressions will have differing relationships with language at the vocabulary spurt session

Gestures and facial affective expressions will have differing relationships with language at the vocabulary spurt session. The final prediction concerned differing relationships between gesture and language, and separately, affect and language. Because gesture has been suggested to facilitate language learning (e.g., Bates, 1976; Butcher & Goldin-Meadow, 2000; Camaioni et al., 1991; Iverson & Goldin-Meadow, 2005), while facial affect expressions have been suggested to hinder language development (Bloom, Beckwith, & Capatides, 1987; Bloom & Capatides, 1987), we hypothesized that if words appeared in coordinated bouts, they would more likely be accompanied by gestures than by affect. To address this prediction, the proportion of words in coordinated bouts that occurred with gestures was calculated and compared to the proportion of words in coordinated bouts that occurred with affect at the pre-spurt, spurt, and post-spurt sessions using paired samples *t* tests. Overall, gestures were significantly more likely to occur with words in coordinated bouts than were affective expressions. Results revealed significant differences at the pre-spurt session, $t(13) = 3.50$, $p = .004$ ($M_{gestures} = .72$, $SD = .39$; $M_{affect} = .12$, $SD = .26$), the spurt session, $t(15) = 3.79$, $p = .002$ ($M_{gestures} = .70$, $SD = .36$; $M_{affect} = .11$, $SD = .28$), and the post-spurt session, $t(17) = 7.08$, $p = .000$ ($M_{gestures} = .77$, $SD = .20$; $M_{affect} = .11$, $SD = .15$).

3.4 INDIVIDUAL DIFFERENCES

A further aim of the current study was to investigate whether individual differences in the rate of word acquisition predict individual differences in the expression of system-wide instability. It was expected that infants who experienced a more dramatic transition in vocabulary development, marked by an inflection point in the rate of word learning would show evidence of greater system-wide instability than infants who experienced a more gradual vocabulary spurt. Because instability dictates decoupling of previously organized behaviors, it was predicted that differences between groups would be most apparent in the frequency with which children coordinate communicative expressions in general, and newly emerging behaviors (i.e., speech) in particular.

3.4.1 A procedure for identifying "logistic" vs. "quadratic" vocabulary spurts

A procedure for identifying "logistic" vs. "quadratic" vocabulary spurts. The goal of these analyses was examine individual differences in communicative coordination by classifying the

18 study participants into one of two groups based on whether their rates of new word acquisition were best modeled by a logistic function ("logistic spurters") or a quadratic function (i.e., "quadratic spurters;" Ganger & Brent, 2004). These two functions were chosen because both are among the most plausible representations of vocabulary rate over time. However, only the logistic function has an inflection point (i.e., a specific point of rapid change surrounded by points of slower change). Figures 4a and 4b illustrate this distinction and preview the strategy used to identify a spurt.

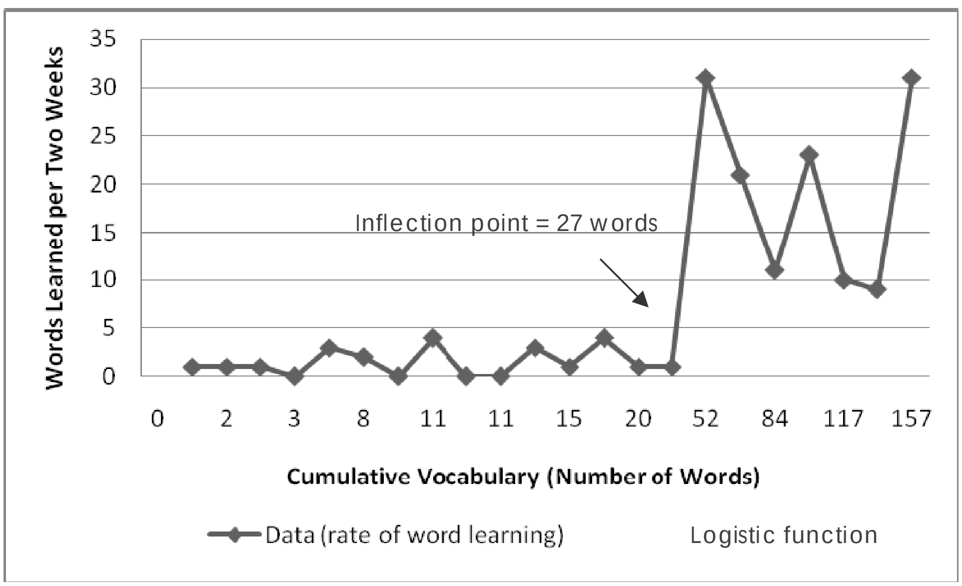

Figure 4a A logistic function superimposed on data from sn 42015

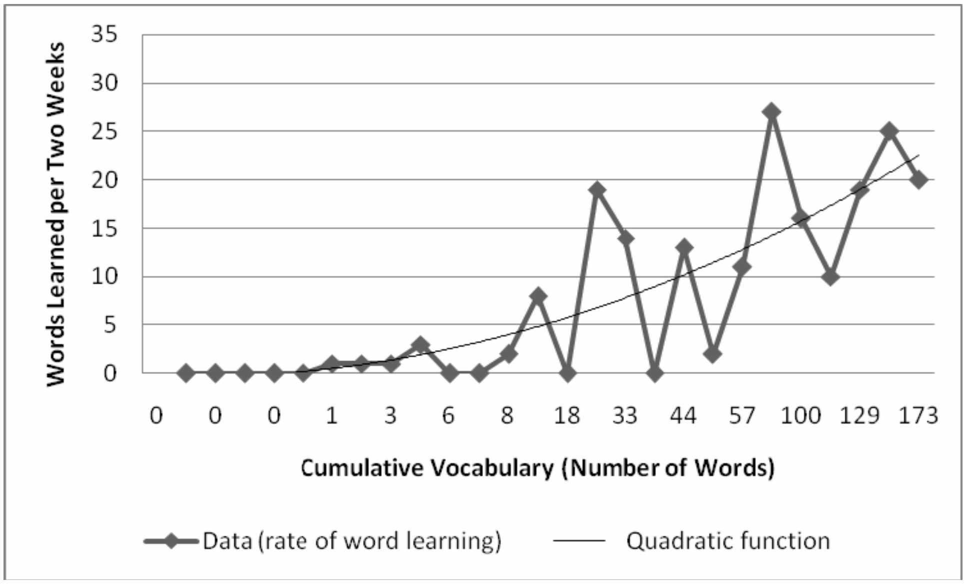

Figure 4b A quadratic curve superimposed on slightly modified data from sn 30109

A logistic function takes the general form $y = a / (1 + e^{-b(x-c)})$ and involves three parameters, *a*, *b*, and *c*. Parameter *a* corresponds to the rate of learning after the transition, or the asymptote. Parameter *b* corresponds to the length of time over which the transition occurs, or the slope of the function at the transition point; and parameter *c* corresponds to the point at which the transition occurs, also known as the inflection point. A quadratic function has the general form $y = ax^2 + bx + c$ and also involves three parameters (but not an inflection point). Here, *b* corresponds to the steady increase in word-learning rate, *a* corresponds to the steady acceleration in word-learning rate, and *c* is a constant defining where the function crosses the vertical axis.

Both models were fit to each child's data independently using SPSS for Windows.[3] Three separate criteria were used to determine which model was the best fit for the individual data. Children had to meet all three criteria to be classified as a logistic spurter. If all of the criteria were not met, children were placed in the quadratic spurter group.

First, the two models were compared for goodness of fit using R^2 values. The model with the higher R^2 was considered potentially to be the better fit. However, to make the comparison more rigorous, we also computed likelihood ratios (LLR) for the two models, or the ratio of the probability of the observed data points under one model (the logistic) to their probability under an alternative model (the quadratic). LLRs, computed using the formula $[(\textit{Quadratic RMS Residuals}) / (\textit{Logistic RMS Residuals})]^{\textit{number of observations}}$, are typically given in (base 10) logarithms. Thus, a ratio of 100:1 is a log of 2, and 10:1 yields a log of 1. Although a ratio of 100:1 is necessary to be very confident of the result, a ratio of 10:1 was considered acceptable. Therefore, the log of the LLR had to be 1 or larger to indicate that the logistic model fit better than the quadratic model.

The final criterion for determining best fit was whether the model computed a reasonable inflection point. For this analysis, any inflection point greater than 20 words was considered acceptable. A minimum of 20 words was selected because many investigators agree that before 20 words is too early for a true spurt (e.g., Lifter & Bloom, 1989). Ganger and Brent (2004) also set a ceiling of 50 words for the inflection point. However, we chose not to adhere to such a stringent a criterion because it has been documented that many children achieve a vocabulary spurt after their productive vocabularies have reached 50 words (D'Odorico, Carubbi, Salerni, & Calvo, 2001; Goldfield & Reznick, 1990; Rescorla, Mirak, & Singh, 2000) and because SPSS's logistic model-fitting algorithm will predict an inflection point somewhere in the data, even if it occurs beyond the data collected.

Using these three criteria, our analyses indicated that 11 of the 18 participants qualified as "logistic spurters." Table 4 displays the inflection points, R^2 values, LLRs, and group status for each of the 18 children. With regard to the 11 participants in the logistic spurter group, 45% were male and 73% were later-born, with a mean age at the vocabulary spurt equal to 15.64 months (SD = 1.12). Of the seven participants in the quadratic group, 27% were male and 43%

were later-born, and the mean age at the spurt was 17.14 months (*SD* = 0.63). Data relevant to predictions concerning individual differences in the impact of the vocabulary spurt are presented below.

Table 4 Testing for "Logistic" vs. "Quadratic" Vocabulary Spurts

SN	Logistic R^2	Quadratic R^2	LLR[a]	Inflection point	Group
11605	0.682	0.687		11[b]	Quadratic
12061	0.963	0.979		33	Quadratic
21169	0.950	0.975		104[c]	Quadratic
29325	0.646	0.613	≥ 2	40	Logistic
30109	0.357	0.349		9[b]	Quadratic
30160	0.673	0.655	≥ 1	103[c]	Logistic
36637	0.958	0.944	≥ 2	131[c]	Logistic
42015	0.838	0.708	≥ 2	29	Logistic
45699	0.964	0.962	≥ 1	24	Logistic
47517	0.807	0.821		57	Quadratic
47761	0.923	0.857	≥ 2	31	Logistic
50859	0.905	0.842	≥ 2	35	Logistic
53310	0.822	0.767	≥ 2	53	Logistic
54250	0.476	0.360	≥ 2	24	Logistic
59771	0.945	0.982		49	Quadratic
69394	0.542	0.521	≥ 1	23	Logistic
71415	0.794	0.824		41	Quadratic
85303	0.919	0.874	≥ 2	33	Logistic

Note. SN = subject number; LLR = log likelihood ratio.

[a]LLRs < 1 are not given. [b]Inflection points less than 20 were not accepted based on the widespread opinion that 20 words is too early for a true spurt (e.g., Lifter & Bloom, 1989). [c]In the original criterion proposed by Ganger and Brent (2004), inflection points greater than 100 were not accepted However, we adopted a less conservative approach that considered infants with inflection points greater than 20 to be candidates for a true spurt.

To verify that children in the two spurter groups did not differ in the production of new words at the spurt session, a 2 (Group) x 3 (Observation) repeated measures ANOVA was conducted using the mean number of words produced at each session. Results revealed a significant main effect of Observation, $F(2, 32) = 3.82$, $p = .033$. However, neither the main effect of Group, $F(1, 16) = .08$, $p = .959$, nor the Group x Observation interaction, $F(2, 32) = .003$, $p = .919$, were significant, indicating that children in both groups showed a peak in new word production at the spurt session. These data confirm the observation of a lexical spurt in *all participants* regardless of whether their vocabulary growth curve fit a logistic or quadratic function.

3.4.2 The relationship between vocabulary spurt status and instability in the communicative system

The relationship between vocabulary spurt status and instability in the communicative system. We re-analyzed the data relevant to the two predictions having to do with the effects of instability on the temporal patterning and coordination of specific communicative behaviors. The first analysis examined the overall occurrence of behavioral coordinations, while the second focused specifically on newly emerging behaviors (i.e., words; new words) and the likelihood that these behaviors would be temporally coordinated with other communicative behaviors. Data were arcsine transformed and then subjected to 2 (Group: logistic spurters, quadratic spurters) x 3 (Observation: pre-spurt, spurt, or post-spurt) repeated measures ANOVAs.

If logistic spurters are experiencing greater systemic instability than quadratic spurters, they should exhibit reduced frequency of coordination of communicative behaviors at the spurt session. The mean proportion of communicative attempts that were coordinated bouts are presented separately for logistic and quadratic spurters in Figure 5a. As can be observed in the figure, the logistic spurters experienced a clear drop and subsequent rebound in coordination at the vocabulary spurt, while quadratic spurters appeared less affected by this transition. Results indicated that the main effects of Observation, $F(2, 32) = 1.67$, $p = .204$, and Group, $F(1, 16) = 2.95$, $p = .105$ were not statistically reliable. However, the Group x Observation interaction was significant, $F(2, 32) = 7.26$, $p = .003$. Simple effects analyses conducted to assess the source of the interaction indicated that the logistic spurter group showed a significant decrease in relative frequency of coordination between the pre-spurt session and the spurt session, $p = .016$, and a marginally significant increase between the spurt session and the post-spurt session, $p = .053$, while there was no significant difference across sessions for the quadratic spurter group, *ns*.

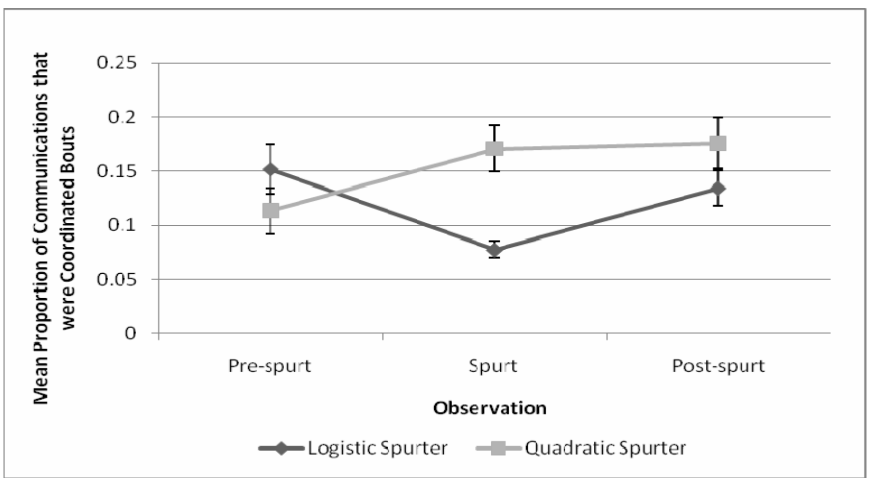

Figure 5a Mean proportion of all communicative attempts that were coordinated bouts

The second set of analyses focused on the effects of systemic instability on the expression and coordination of speech, a newly emerging and particularly vulnerable communicative behavior. It was first predicted that group differences would be evident in the mean proportion of words that were produced alone, such that words would be more likely to occur alone at the spurt session for logistic than for quadratic spurters. These data are presented for logistic and quadratic spurters in Figure 5b. As is evident, logistic spurters showed a strong peak and decline in words produced alone, while there was a lack of change across sessions in the quadratic spurter group. A 2 (Group) x 3 (Observation) repeated measures ANOVA carried out on these data revealed no reliable main effect of Observation, $F(2, 34) = 1.84$, $p = .175$, or Group, $F(1, 16) = .58$, $p = .457$. However, the Group x Observation interaction was significant, $F(2, 34) = 3.63$, $p = .038$. Follow-up simple effects analyses indicated that for logistic spurters, there was a peak in words produced alone from the pre-spurt session to the spurt session, $p = .021$, and a decline from the spurt session to the post-spurt session, $p = .009$, while the quadratic spurter group did not differ across sessions, *ns*.

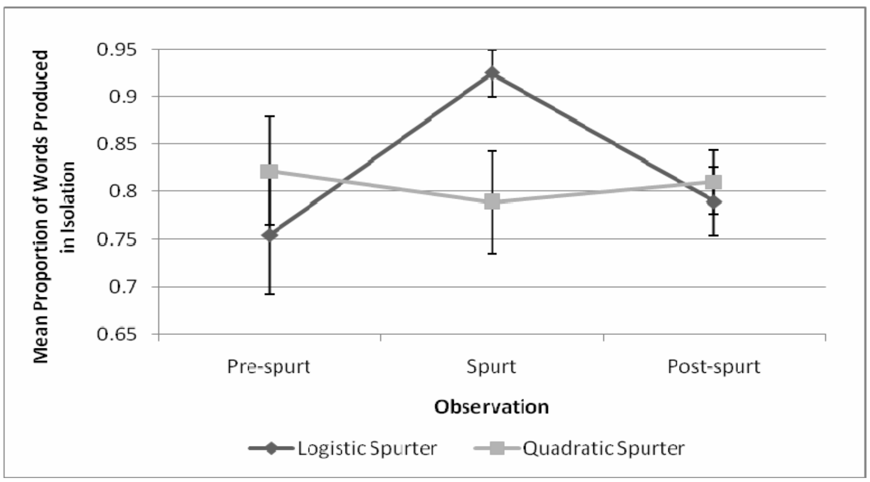

Figure 5b Mean proportion of all words that were produced in isolation

Finally, we assessed whether the shape of the vocabulary growth curve (i.e., logistic vs. quadratic) affected the *coordination* of new words. It was predicted that logistic spurters would be less likely to coordinate new words at the vocabulary spurt session than quadratic spurters. To address this prediction, we examined the percentage of participants in each group who produced at least one coordinated bout involving a new word. These data are presented in Figure 5c. As is apparent in the figure, the two groups did not differ at the pre-spurt and post-spurt sessions. In contrast, at the spurt session, approximately 71% of the children in the quadratic spurter group produced at least one coordinated bout involving a new word at the spurt session, while only approximately 36% of the children in the logistic spurter group produced at least one bout involving a new word. However, this pattern was not statistically reliable, Fisher's exact test p = .167, one-tailed.

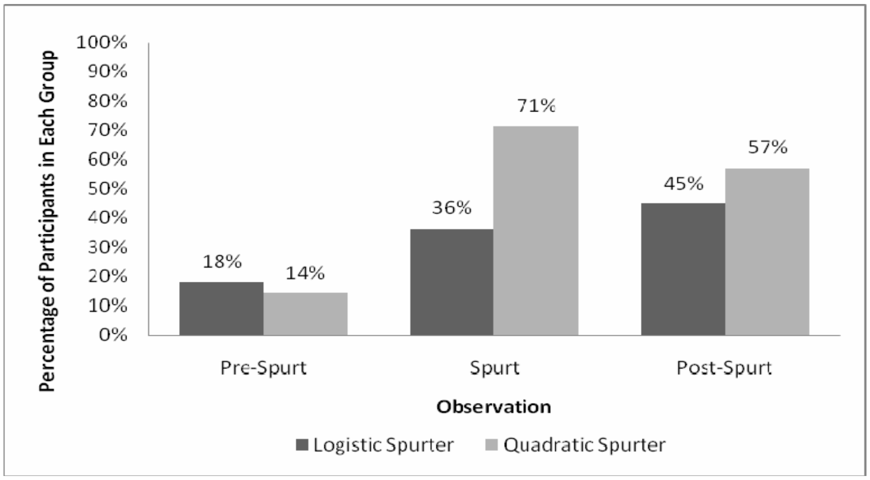

Figure 5c Percentage of participants who produced at least one coordinated bout involving a new word

4.0 DISCUSSION

This research was designed to examine how the onset of the vocabulary spurt, a major communicative milestone, impacts the organization of the communicative system. The study asked whether the closely linked relationship between gesture, affect, and speech is altered as the linguistic system undergoes a period of significant growth. The study had three major goals. The first was to provide a general picture of infants' communicative repertoires at the time surrounding the vocabulary spurt. The second was to gather data regarding a set of hypotheses derived from a dynamic systems model of development. These predictions had to do with effects of instability on the patterning and coordination of different expressive behaviors, differences between newly emerging and well-established communicative behaviors, and the specific relationship between speech and other communicative behaviors. The third goal was to examine individual differences in the vocabulary spurt and determine the extent to which children who experienced a more dramatic transition in vocabulary development showed evidence of greater system-wide instability.

4.1 HOW DO INFANTS COMMUNICATE VIA THE COORDINATION OF COMMUNICATIVE BEHAVIORS?

Previous studies have demonstrated that infants coordinate actions between different behavioral modalities into specific, nonrandom patterns; however, most have only focused on the association between two individual behaviors (e.g., co-occurrence of infant gaze direction with facial expressions or vocalizations; Adamson & Bakeman, 1985; Kaye & Fogel, 1980; Weinberg & Tronick, 1994). To our knowledge, the present study is the first to consider links between a broader set of communicative behaviors: facial affect expressions, gestures, vocalizations, and words. Results indicated that all of the infants in this study combined behaviors from multiple modalities to deliver a communicative message, and they did so frequently. These findings are consistent with the observation that the temporal organization of expressive behaviors is a robust feature of infant behavior (e.g., Yale, Messinger, Cobo-Lewis, Oller, & Eilers, 1999; Yale, Messinger, Cobo-Lewis & Delgado, 2003; D'Odorico, Cassibba, & Salerni, 1997).

However, this study extends current research by considering behavioral coordination in the later stages of infancy when more dominant forms of communication (e.g., speech) begin to emerge. We found evidence for the increasing integration of speech into patterns of coordination, with coordinated bouts involving words becoming more frequent after the onset of the vocabulary spurt. This is consonant with work demonstrating that gesture plus word combinations increase as children transition to two-word speech (Butcher & Goldin-Meadow, 2000), a linguistic milestone that is believed to occur shortly after the vocabulary spurt (e.g., Bloom, 1970; Brown, 1973; Bruner, 1983; Camaioni, 2001). Therefore, as children begin to acquire and produce words with more ease, they are better able to enlist other behaviors to work together with speech to create a single message.

There was also indication that the nature of these coordinated bouts began to approximate the adult model in terms of both composition and temporal patterning. In adult communication, speech is tightly linked in time with nonverbal communicative behaviors such as gestures, with the gesture movement (the stroke) executed as the co-expressive word or phrase is articulated (McNeill, 1992). When infants in this study produced coordinated bouts, they most often temporally combined two behaviors, one of which was very likely to be a gesture (e.g., McNeill, 1992). We also noted a tendency for temporal synchrony to improve over time, a finding consistent with reports that the adult pattern of gesture-speech synchrony is evident by the time children make the transition to two-word speech (Butcher & Goldin-Meadow, 2000: McNeill, 1992). Finally, the duration of coordinated bouts became progressively briefer, which suggests that as children become more adept at combining communicative behaviors in a single production, the temporal union of behaviors is strengthened.

Moreover, the communicative behaviors observed here appear to play somewhat contrasting roles in infants' communication. It may be that during linguistic transitions, one behavior in particular serves as an "organizer" for communication. Although we did not test this idea directly, the fact that the vast majority of coordinated bouts (approximately 90 percent) involved a gesture suggests that gestures play an important role in organizing communicative coordinations during the vocabulary spurt. Two findings provide further support for this view.

First, the majority of asynchronous bouts were initiated by a gesture. It is possible that gestures, once produced, may influence, or "pull in," other communicative behaviors. This idea parallels the dynamic systems principle of entrainment (Iverson & Thelen, 1999), in which sufficient activation in one component of a system pulls in or entrains the activity of a complementary component. Older, more established behaviors are considered the best candidates for entrainment. Gestures, having been the preferred mode of communication since the emergence of first words (Bates et al., 1979; Bates, Camaioni, & Volterra, 1975; Caselli, 1990; Lock, Young, Service, & Chandler, 1990; Petitto, 1988), are indeed a stable component of the communicative system when children are entering the vocabulary spurt and thus have the most potential for entraining other behaviors.

Second, words were more likely to be accompanied by gestures than facial affect in coordinated bouts. In early infancy, when communication primarily takes place within the context of face-to-face situations, affective facial expressions appear to dominate social interchange (Adamson & Bakeman, 1985; Kaye & Fogel, 1908; Tronick, Als, & Adamson, 1979; Yale, Messinger, Cobo-Lewis, & Delgado, 2003). And although the link between facial affect expressions and vocal behavior is well-established in early infancy, with the emergence of intentional communication, gestures come to the forefront in social interactions (Bates, 1976; Bates et al., 1979) and expressions involving facial affect begin to decrease (Adamson & Bakeman, 1985). Results from the present study suggest that affect is indeed a less integral part of communicative coordinations in later infancy. The scarcity of affective expressions during communicative utterances involving speech is consistent with the line of work by Bloom and colleagues that suggest the expression of affect may even play a hindering role in the development of language (Bloom, 1994; Bloom, Beckwith, & Capatides, 1987; Bloom & Capatides, 1987).

The importance of gesture's role in the development of intentional communication has been acknowledged in previous studies. While there is some indication that gesture facilitates the development of language and may play a supportive role in linguistic transitions (Baldwin, 1991, 1993; Bates, 1976; Bates et al., 1979; Bruner, 1975; Butcher & Goldin-Meadow, 2000;

Butterworth & Morrissette, 1996; Camaioni, Caselli, Longobardi, & Volterra, 1991; Iverson & Goldin-Meadow, 2005), many studies have also demonstrated how gesture's role changes with development (Acredolo & Goodwyn, 1988; Butcher & Goldin-Meadow, 2000; Iverson, Capirci, & Caselli, 1994; Iverson & Thal, 1998). Findings from the present study add to these accounts and support a developmental scenario in which gestures begin as the primary form of intentional communication, then assume a communicative position that is relatively equivalent to speech, and finally shift to a new role as a secondary support system integrated with speech (Butcher & Goldin-Meadow, 2000; Iverson, Capirci, & Caselli, 1994), the role that is observed in adult communication (McNeill, 1992).

Taken together, it seems that the gestural, affective, and vocal modalities develop as complimentary systems of expression. However, the communicative role played by each modality changes over the course of development, thus highlighting the dynamic organization of the communicative system. While affect is an important integrated feature of communication in early infancy, gesture appears to come to the forefront later in infancy, with speech eventually becoming the predominant form of communication. Importantly, however, older behavioral forms do not disappear once more "effective" means of communication emerge; rather, they simply assume a different role.

4.2 WHAT IS THE IMPACT OF THE VOCABULARY SPURT ON THE COMMUNICATIVE SYSTEM?

From dynamic systems view, transition periods in development are ideal for viewing underlying processes of change (Thelen & Smith, 1994). Thus, a second question had to do with the extent to which the vocabulary spurt impacts the communicative system as a whole. It was expected that the instability produced by the vocabulary spurt would alter existing patterns of behavior such that the production and temporal patterning of communicative behaviors are reorganized. Findings were consistent with this general prediction in two ways.

During the vocabulary spurt, infants are not only acquiring words at an extraordinarily rapid pace, but these words appear to have a particularly fragile status. Infants in this study produced, on average, twice as many words and more than three times as many new words at the vocabulary spurt session than the pre-spurt session. However, words were more likely to be used alone when recruited for communication at the vocabulary spurt session. In contrast, prior to the vocabulary spurt, as words were being acquired at a slower pace, they often appeared in coordination with gestures and facial affect expressions. Following the vocabulary spurt, as children gained experience with specific words and the system regained stability, words appeared in coordinated bouts with increased frequency. This pattern is consistent with the notion that language is particularly effortful during the vocabulary spurt and is more vulnerable to disruption (Gershkoff-Stowe, 2001, 2002).

Further support for the fragile status of language at the vocabulary spurt comes from the finding that words coordinated with other communicative behaviors were more likely to be well-practiced words (i.e., older words that had part of the infants' vocabularies for more than one month) than new words. This difference between old and new words was particularly striking at the spurt and post-spurt sessions. Practice appears to strengthen the delicate status of speech making it an important determinant of systemic configurations. This parallels earlier findings demonstrating that as individual words are practiced in production, they become stronger and more resistant to naming errors (Gershkoff-Stowe, 2001, 2002). Thus, it seems that practice with novel behaviors increases the likelihood that they will become more stable and increasingly integrated with other components in the system (Thelen & Smith, 1994).

However, findings from the current study also suggest that the instability produced by the vocabulary spurt is manifested in ways that are not specific to word production. First, a decoupling of communicative behaviors was observed at the vocabulary spurt session, a time when increased effort was presumably dedicated to word learning. Prior to the vocabulary spurt, communicative behaviors such as gesture, facial affect, vocalizations, and words were organized into established patterns of communication; however, when children began to acquire words rapidly, these patterns were disrupted. This is consistent with previous work documenting U-shaped changes in development, in which behaviors apparently disappear or regress, only to resurface later (Bybee & Slobin, 1982; Cashon & Cohen, 2004; Gershkoff-Stowe, 2001, 2002; Gershkoff-Stowe & Thelen, 2004; Namy, Campbell, & Tomasello, 2004). U-shaped developmental phenomena are considered particularly valuable because they direct our attention to places where reorganization might be taking place (Goldin-Meadow, 2004).

Additionally, the onset of the vocabulary spurt was associated with changes in the composition of coordinated bouts. Specifically, gesture + affect combinations and affect + vocalization combinations peaked at the vocabulary spurt session, while gesture + vocalization combinations were consistently prominent over the observation period. These findings are noteworthy for several reasons. First, they underscore the concept of soft-assembly by demonstrating a continual adaptation and flexibility among constituent components of the communicative system. They also highlight ways in which changes or disruption in one component of a system can affect the configuration of other components. Finally, these results indicate that during times of instability there may be a preference for well-established patterns of coordination (e.g., configurations involving gestures, affect, and vocalizations), patterns that have been a part of infants' communicative repertoires since before the onset of the first word (e.g., Adamson and Bakeman, 1985; Kasari, Sigman, Mundy & Yirmiya, 1990; Yale, Messinger, Cobo-Lewis, & Delgado, 2003; Weinberg & Tronick, 1994).

The data reported here are consistent with the possibility that infants do not abandon more "primitive" forms of behavior as they acquire new skills. Rather, they continue to draw upon earlier developing skills at a time when new skills are emerging. Further empirical support for this interpretation comes from work in the area of motor development (Adolph, 1997, 2000; Corbetta & Bojczyk, 2002; Corbetta & Thelen, 1996; Thelen, 2000; Thelen & Ulrich, 1991). For example, Corbetta and Bojczyk (2002) demonstrated that infants returned to two-handed reaching when they were leaning to walk. Prior to the onset of walking, most infants were able to produce well-coordinated movement patterns that involved the extension of one arm in reaching for objects. When they began to walk, however, those infants increased their rate of two-handed reaching. Then, a few to several weeks later, when the infants gained better balance control, they returned to unimanual reaching.

In sum, our findings are consistent with a dynamical view of development, in which behavior is constantly changing and inherently flexible. Developing systems, such as the communicative system, are comprised of many interacting parts that assemble and reassemble during periods of transition. Instability in the linguistic component has far-reaching effects on the entire communicative system that are manifested in multiple and varying ways. Newly emerging forms (i.e., speech) are initially unstable but are gradually integrated with practice and support from well-established patterns of behaviors. Future work examining temporal patterns of multiple, diverse behaviors at other linguistic milestones (e.g., onset of the first word, the transition into two-word speech) will shed further light on the relevance of systemic disruption for engendering changes in communication and on general processes underlying development.

4.3 ARE THERE INDIVIDUAL DIFFERENCES IN THE WAY IN WHICH THE VOCABULARY SPURT IMPACTS COMMUNICATION?

In light of well-documented accounts of widespread individual variability in the nature of the vocabulary spurt (Dale & Goodman, 2005; Fenson et al., 1994; Ganger & Brent, 2004; Goldfield & Reznick, 1990; Goodman et al., 1999), a final question of interest was whether these individual differences were related to instability in the communicative system.

Our results suggest that the vocabulary spurt is a real developmental phenomenon; however, there is evidence to suggest that it may not necessarily be a single, unified phenomenon. All of the infants in the current study gave evidence of a vocabulary spurt using the commonly used *threshold approach,* which requires that a threshold of words per unit of time must be crossed (Mervis & Bertrand, 1994; Gopnik & Meltzoff, 1987; Lifter & Bloom, 1989; Choi & Gopnik, 1995; Goldfield & Reznick, 1990; Poulin-Dubois, Graham, & Sippola, 1995; see methods for specific criteria). However, within this group, two different patterns of vocabulary growth were identified using statistical modeling techniques (Ganger & Brent, 2004). Children whose vocabulary growth consisted of a discrete transition from a slow learning stage to a faster learning stage (i.e., logistic spurters) showed greater evidence of system-wide instability specifically at the vocabulary spurt session, as indicated by: a) a drop in overall coordination of communicative behaviors; b) an increased likelihood that words would be produced in isolation; and c) less frequent coordination of new words. In contrast, children whose vocabulary growth was best described as continuous incremental improvement (i.e., quadratic spurters) did not demonstrate as dramatic a change in these variables across the three sessions.

Previous accounts of the vocabulary spurt claim that it is driven by major cognitive change such as the “naming insight” (e.g., Dore, 1978; Reznick & Goldfield, 1992), or dramatic advances in object concepts (Gopnik & Meltzoff, 1987; Lifter & Bloom, 1989; Mervis & Bertrand, 1994; Poulin-Dubois, Graham, & Sippola, 1995). However, the fact that roughly half of the children in our sample experienced a logistic spurt while the remaining children experienced a quadratic spurt suggests at the very least that the spurt may not reflect a universal cognitive transformation. Any theory that attempts to explain the vocabulary spurt must account for individual variation in spurt patterns.

Although variability in vocabulary growth is increasingly emphasized, no study to date has examined this variability in specific ways. Our data suggest that this is an important endeavor for future research. For example, are there specific factors that can differentiate logistic spurters from quadratic spurters? It is of note that one distinguishing feature between groups in the present study was age of vocabulary spurt onset, with logistic spurters exhibiting an earlier spurt than quadratic spurters. Factors such as these merit further consideration in future studies. Research would also benefit from investigating correlates of more unusual growth trajectories, such as those of children who demonstrate a late onset vocabulary spurt (“late spurters;” e.g., D’Odorico, Carubbi, Salerni, & Calvo, 2001), children who appear to undergo two spurts (Goodman et al., 1999; Dale & Goodman, 2005), and children who do not exhibit any vocabulary spurt at all. Investigations attempting to examine this variability would do well to explore additional mechanisms internal to the child and even perhaps other potentially significant factors such as environmental influences.

4.4 SUMMARY

Taken together, the data from the present study suggest that the vocabulary spurt is a time of considerable change that alters existing communication patterns. The findings presented here are consistent with the notion that during a transition in communicative development, previously stable and organized behaviors are disrupted. Through practice and experience, however, new behaviors are increasingly strengthened and integrated. The results also highlight both intra- and inter-individual differences in the developmental trajectories of various communicative behaviors. The milestone-based design offered a unique approach to studying infant development by permitting the examination of changes in behavior as they specifically related to the emergence of a new communicative skill. It is hoped that the application of this type of approach in future investigations will increase our understanding of the processes underlying developmental change. Overall, this study provides an example of the richness of the communicative repertoire of the older infant and underscores the fruitfulness of an integrated approach to the study of early communication.

APPENDIX A

CODING MANUAL

General Rules

1. If a gesture is not well-defined, it may not be ratable. It is better to not rate a gesture (or rate is as dg/rg help) than to categorize it haphazardly without sufficient information.
2. Do not code any behavior that is obscured (e.g., by the caregiver blocking the camera's view of the child). Make a note in the comments box that a behavior was obscured or code gesture help then ambiguous.
3. Only code communicative behaviors that are truly spontaneous on that part of the infant should be coded. Episodes in which another person's speech or movement may have elicited the infant's communicative bid should not be coded.

Codes

The primary task is to identify episodes of communicative utterances which may take the form of gestures, vocalizations, or affective facial expressions. Once identified, these behaviors should be coded for onset and offset time and should be modified accordingly.

Communicative Behaviors

Gestures

Gestures are a form of intentional communication, that is, they are directed toward another person in order to communicate. These gestures are spontaneous and voluntary and can sometimes hold specific meanings. There are two main types of gestures: deictic gestures and representational gestures.

Deictic Gestures. These gestures are communicative signals that express the child's communicative intent to request or declare. They refer to an object, location, or event by directly touching it or indicating the referent. They express the child's communicative intent to call attention to certain objects, locations, or events.

Point/Point + Eye Contact (poi/pec): With clear articulation of the index finger the child points to a proximal object/toy or an unattainable object (poster on the wall). Points may also be used to indicate the child's desire for an object or event. In some instances, a child may reach and then turn the reach into a point or vice-versa. Points should only be coded when the index finger is extended and adjacent fingers are noticeably inclined downward, or away from the index finger and toward the palm. Pushing or scratching a toy with one finger should not be considered a point. However, touching a toy with an index finger with the hand in a pointing configuration should be considered a point Take note that there are instances when a child points with an object or toy as the pointer (in place of the index finger). Although this gesture may look similar to a show, if there is evidence of leaning or fully outstretching the arm, it may be a point with object. If this is the case, make sure to describe the gesture in the comments box.

A point may be rated as occurring with or without simultaneous (alternating) eye contact with the social partner. The eye contact may be a brief event superimposed on a longer period of pointing; however, the eye contact and point must be simultaneous at some point during the bid to be considered a point + eye contact.

Points to objects beyond the frame of view of the camera should be coded under Initiating Joint Attention unless additional information (e.g., reaching or verbalization) is indicative of a request.

Reach/Reach + Eye Contact (rea/rec): The child extends his/her arm with an open palm or extension of the arm, often with repeated opening/closing of the hand. *Do not score if the child actually obtains the object by him/herself without assistance from the adult.* Arms may be up but hands also need to be articulated to be considered a reach (arms up without hand articulation may simply be a results of over-stimulation). A reach bid ends when the child retracts his/her arm or the arm relaxes.

Reaches may or may not include eye contact. If the child does combine eye contact with reaching, the eye contact may be a brief event superimposed on a longer period of reaching; however, eye contact and gesture must be simultaneous at some point during the bid.

Give/Give + Eye Contact (giv/gec): The extension of the arm with an object in hand with the intention of the child for the other person to take the object. The child pushes/throws/hands the object to the other person in order to request that the caregiver repeat an action ("do it again,") or to get rid of an object, or to offer the object in an act of "sharing." The child may also hold an object out toward the caregiver. Typically the latter is toward the caregiver's hands or body as opposed to up toward the caregiver's face, as in an IJA show (see below).

Gives may be rated as occurring with or without simultaneous eye contact or may/may not involve eye gaze alternation. The eye contact may be a brief event superimposed on a longer period of giving; however, the eye contact and give must occur at the same time during the bid (overlap) to receive the code Give + Eye Contact. If the give and eye contact occur one after the other, they should be coded as two distinct behaviors.

Gives may be difficult to differentiate from shows. So, to help differentiate between the two, during a Give, the child may continue to hold the object out at midline (not up), and sometimes vocalizes as well, to get the partner to take the object (i.e., persistence). You may also see some degree of leaning or straining on the part of the child. If the social partner previously extended an arm/hand to take or request the object previous to the child extending the object, it does not count as a gesture-it is simply a transfer of an object. Also, be wary of "dumping," or repeated giving or placing an object to the caregiver without eye contact.

Show (sho): Child presents the toy/object in the direction of the caregiver's face (inclined) and makes *eye contact* with the tester. The object should be presented relatively still for a second or two. Shows, by definition, involve simultaneous (overlapping) eye contact.

Shows may be confused with Gives. Shows are usually directed to the face, whereas Gives are usually directed to the caregiver's hands or body. Shows are typically brief with the child retracting the proffered object. Gives usually involve maintained gestures until the caregiver retrieves the object. If the child resists (albeit briefly) when the caregiver attempts to retrieve the object, the behavior should be coded as a Show. Observations of any hesitation or resistance to relinquishing the object may be used as indicative of a Show.

Deictic Gesture Help (dgh): When you're not sure what kind of gesture you're observing but it appears to be deictic, choose this code.

Representational Gestures. These gestures refer to an object, person, location, or event through hand movement, body movement, or facial expression. These gestures differ from deictic gestures in that they represent specific referents and their basic semantic content does not vary much with the context. Deictic gestures simply "point out" a given referent whereas representational gestures "stand for" some referent, or a class of referent or relations. All of these gestures must be empty-handed. Additionally, these gestures occur much less frequently than deictic gestures.

Conventional (con): Culturally defined signs or social markers (e.g., shaking head no, nodding yes, waving bye-bye/hello, shrugging shoulders for "I don't know," clapping for yay/good, flipping hands for where/I don't know). Gestures such as head nodding and clapping must follow through a full cycle (full up and down or side-to-side motion) to be coded. Gestures conventional to infant-mother pairs (e.g., putting hands up in the air spaced far apart for big) may also be coded. These types of gestures are coded as conventional only if they are observed more than once throughout the play session.

Predicate (pre): Describes qualities or characteristics of an object or situation (e.g., waving hands for hot, raising the arms high for tall). Predicates are generally created during play, and thus qualify as Conventionals. These two categories may be collapsed at a later time.

Nominal (nom): Provides a label for a specific object. They can act as labels by either (a) replicating the action performed by an agent involving the object (e.g., making the hand like a cup and pretending to drink for "cup") or (b) copying the movement that would be performed by the object itself (e.g., flapping arms for bird, wiggling nose for rabbit). Like predicates, nominals may be collapsed with the broader conventional category.

RG Help (rgh): When you are not sure what kind of gesture you are dealing with, but it appears to be a representational gesture, choose this category.

Note: Be sure to code discrete behaviors when there are interruptions between gestures. Interruptions are indicated by a pause or (slight) relaxation of the arm, or the point of reference has changed (i.e., the child shifts from pointing at a ball to pointing at a cup).

Facial Affect

Action Units (based on Ekman and Friesen's FACS and Oster's BabyFACS): AU12 (lip corner pull); Brows lowered/furrowed; AU6 (mouth opening); AU26c-e/27 (cheek raising); AU5 (raised eyelids); AU1+2 (raised brows)

Positive Emotionality/Joy. Defined by the presence of upward lip corner pull (AU12) and any combination of the following: lip corner pull and mouth opening (AU6) and/or cheek raising (AU26c-e/27)

Negative Emotionality/Distress. Defined by the presence of downward lip corner pull (AU12) and brows lowered/furrowed and/or mouth opening and/or cheek raising

Surprise/Interest. Defined by the presence of one or any combination of the following three action units: raised brows, raised eyelids, or mouth opening

Each facial affect expression is modified by level of intensity and is given a rating of 1 (low intensity), 2 (medium intensity), or 3 (high intensity)

Vocal Utterances

Code all nonmeaningful and meaningful vocalization regardless of whether or not it occurs in coordination with another communicative behavior.

Vocalization (voc). Nonmeaningful/uninterpretable vocalization or multiple vocalizations of this kind.

Affective Vocalization (avo). Instances of laughing, squealing, fussing, or crying.

Meaningful Vocalization (mvo). At least one part of the utterance contains a meaningful verbal utterance or a "word" or verbal marker such as "uh huh" (yes), "nuh uh" (no), or "uh oh." Voc's may also be present, but there must be one interpretable word.

Referent/Context

For verbal/gestural utterances, the referent is the object, location, or event that is referred to. The action, attribute, object, or event depicted by a representational gesture is its referent. If the gesture is a conventional representational gesture (or social marker) enter the meaning of the gesture (flip = "I don't know" or "where?"). Code this information in the comments box. Also write a brief description of the interactions (i.e., what's happening, the context of the situation).

FOOTNOTES

[1]Three infants met criteria for a vocabulary spurt less than one month prior to the end of data collection (ages, 18.5, 18.5, and 19 months, respectively). Since a follow up session would not be possible for these 3 infants, they were dropped from the study.

[2]If observation sessions deviated from the prescribed protocol in length, a portion of the first naturalistic period was used to ensure each participant was observed and coded for a total of 30 minutes.

[3]Children's data were represented as rate of new word acquisition (specifically, new words per two weeks) versus cumulative vocabulary (see Ganger and Brent (2004) for a detailed rationale in choosing the dependent and independent variables). A logistic model was fit to each child's data by using the nonlinear regression function of SPSS for Windows and entering the model $asymptote / \{1 + e^{[-slope(words - inflection\ point)]}\}$ by hand. *Words*, the child's cumulative vocabulary level, was the independent variable. *Asymptote*, *inflection point*, and *slope* are parameters that are fit to the child's data. Initial values of the parameters were set as follows: *asymptote* = 3.0, *inflection point* = -0.1, and *slope* = 0.1. These values were chosen in order to be consistent with the method used by Ganger and Brent (2004). We then tested the fit of a quadratic model by using the curve-fitting function of SPSS for Windows and selecting the quadratic option.

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