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Type and frequency of responsiveness matters: The development of infants' social communicative skills and later language development

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TYPE AND FREQUENCY OF RESPONSIVENESS MATTERS: THE DEVELOPMENT OF INFANTS' SOCIAL COMMUNICATIVE SKILLS AND LATER LANGUAGE DEVELOPMENT

by

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CERTIFICATE OF APPROVAL

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MASTER'S THESIS

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This is to certify that the Master's thesis of

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To my mother: her unremitting support,
confidence in me, strength, and encouragement
have truly shaped the person I am today.

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ABSTRACT

Contingent maternal responsiveness has previously been shown to influence the development of many abilities including attachment, language, vocabulary, phonology, attention, and cognitive functioning. In addition, it has been speculated that early contingent interactions may facilitate the development of early social communicative behaviors including joint attention abilities. Examining 13-month-old infant vocal-led interactions with mothers in free play allowed us to look at maternal responses to a specific social communicative interaction. These interactions were then correlated with infants' social communicative abilities as assessed by the Early Social Communicative Scales. Both components were then used to predict later language abilities using the McArthur Communicative Development Inventory: Words and Gestures. Specific responses from mothers during free play and infants communicative abilities were shown to correlate and predict social communicative abilities. Later language abilities were also shown to be predicted by specific responses from mothers during free play and infants' own social communicative skills.

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INTRODUCTION

Learning to respond to episodes of joint engagement and developing the ability to establish and maintain joint attention are important achievements in communicative development (Bruner, 1975; Seibert, Hogan, & Mundy, 1982). Around 9 months of age, infants shift from monitoring social partners to actively initiating and maintaining interactions (Striano, 2001). This developmental change involves being able to follow another's gaze and initiate joint attention within a dynamic interaction with a social partner, eventually including objects in triadic interactions (Bakeman & Adamson, 1984). A hallmark of initiating and maintaining intentional communication is the integration of multimodal prelinguistic behaviors to coordinate visual attention to objects or events with a social partner (Bates, 1979; Bruner, 1975; Bruner & Sherwood, 1976; see also Carpenter, Mastergeorge, & Coggins, 1983).

Extensive research of early social communicative behaviors has documented the stages of communicative development beginning with proto-imperative gestures and continuing to include proto-declarative gestures. The first of these involves infants using their gestural and vocal behaviors in order to have a need met (i.e., to get something they want from someone else). The latter is performed to direct a social partner's attention to an event or object in order to share some attentional state with them. The proto-declaratives are seen as more sophisticated because they require the actor to assume that others have mental states (Bates, 1976; Bates, Camaioni, & Volterra, 1975).

Mundy and colleagues developed the Early Social Communicative Scales (ESCS) assessment to examine and chart the development of such abilities, and to look at their correlations with variables known to effect the development of these skills. Mundy and colleagues have used the ESCS assessment to examine children who are at risk for developing poor social communicative skills (Seibert et al., 1982), the relationship between affective sharing and intersubjectivity (Mundy, Kasari, & Sigman, 1992) and

between communicative skills and early language acquisition (Markus, Mundy, Morales, Delgado, & Yale, 2000; Mundy, Kasari, Sigman, & Ruskin, 1995; Mundy & Gomes, 1998; Mundy et al., 2007), responding to joint attention and early language acquisition (Morales et al., 2000), as well as attentional skills and emotion regulation (Morales, Mundy, Crowson, Neal, & Delgado, 2005). Despite the extensive research on the relationship of early social communicative skills and other behaviors, little is known about the mechanism that underlies the development of the communicative abilities themselves (but see Paavola, Kunnari, & Moilanen, 2005a; Paavola, Kunnari, Moilanen, & Lehtihalmes, 2005b; Rollins, 2003).

The onset of these behaviors has been described by Tomasello (1995) as the '9-month social-cognitive revolution' (see Rochat & Striano, 1999). In this view it is thought that the etiology of initiative social behaviors is rooted in infants' perception of others' goal-related behaviors and the understanding of self and others as intentional agents, which is purported to emerge around 9 months and is fully developed around the end of the first year (Tomasello, 1995; Tomasello, Carpenter, Call, Behne, & Moll, 2005; Tomasello, Carpenter, & Liszkowski, 2007). This rich interpretation of infants' prelinguistic communicative skills states that infants are producing gestures such as pointing between 11 and 12 months of age in order to influence others' mental states (Tomasello et al., 2007). This view assumes that infants have had adequate experience observing others' purposeful actions, leading to the understanding that others' actions are intentional and that infants' own behaviors have resulting consequences on others' actions.

D'Entremont and Seamans (2007) take a leaner, less cognitive approach when providing an explanation for infants' initial proto-declarative gestures, arguing that infants do not have an understanding of self and others as intentional agents until 18-24 months of age. In this view, in order for infants to understand intentions they must first develop an awareness of others' mental states. It seems unlikely, based on prior research,

that infants under the age of two would be capable of understanding that they themselves have intentions, as do others, and that these intentions are the same. D'Entremont and Seamans (2007) note that the information that infants have available about themselves is qualitatively different from the information they gain from observing others and, therefore, they do not have a full understanding of communicative intent (see also Barresi & Moore, 1996; Moore, 2007). According to this group of researchers, infants at this early age are not pointing to direct another's attention; rather, they are aware of where others are attending and find these joint attention episodes to be reinforcing (O'Neill, 1996; Woodward, 1998). Therefore, infants may produce gestures that later are intentional in nature, but when tested prior to 2 years of age, they are more likely to point to enhance interactions rather that to direct adults' attention (Moore & D'Entremont, 2001; but see Liszkowski, 2011; Tomasello et al., 2007).

The onset and emergence of the ability to engage with others for social purposes is extremely important for understanding intentionality, but in contrast to Tomasello's perspective, research suggests that there is a more gradual emergence of social communicative competence that is based on experience in social interactions (Striano & Rochat, 1999; Striano, 2001). The previously described hypotheses are not mutually exclusive; however, what needs to be explained is the mechanism facilitating the development of pragmatic social communicative skills, rather than rationalizing that infants at 9 months have had enough previous experience from watching others' behaviors and, therefore, understand others' intentions. The argument as to whether infants understand intentionality in their own actions or in others at a specific age is somewhat dependent on the stimuli, tasks, and interpretations of data (see debate on the emergence of pointing for an example: D'Entremont & Seamans, 2007; Tomasello et al., 2007). Therefore, it seems more critical and plausible to discuss the underlying factors that influence infants' development of appropriate social communicative skills.

Some studies have begun to examine the experiences that lead to the development of communicative abilities. For example, Straino & Rochat (1999) found that infants who show more attempts to re-engage a social partner in still-face episodes during dyadic interactions also show more advanced joint engagement behaviors in triadic interactions, suggesting that infants may learn from prior experiences in social interactions (Striano & Rochat, 1999). Specifically, Striano proposes that contingencies in prior turn-taking and routine interactions influence the development of social expectations and sensitivity to contingency in dyadic interactions (see also Bruner, 1975; Bruner & Sherwood, 1976; Fogel, 1993; Nadel & Tremblay-Leveau, 1999; Ratner & Bruner, 1978; Rochat & Striano, 1999). Social contingencies are derived from caregiver responsiveness as infant and social partner elicit timely responses from one another through multiple modalities including eye gaze, physical interaction, facial expressions, and vocalizing (e.g., Henning & Striano, 2011; Striano, 2001).

The idea that maternal responsiveness influences communicative development is not new, as many studies have found that contingent responses influence vocal and linguistic development. Experimental studies have shown that infants produce more developmentally advanced, speech-like syllables (termed ‘canonical syllables’-Oller, Eilers, & Basinger, 2001) after receiving contingent feedback to vocalizations (Goldstein, King, & West, 2003; Goldstein & Schwade, 2008). There is also evidence that contingent responses to vocalizations and gestures influence language development (e.g., Bates, 1979; Baumwell, Tamis-LeMonda, & Bornstein, 1997; Desrochers, Morissette, & Ricard, 1995; Laasko, Poikkeus, Eklund, & Lyytinen, 1999; Locke, 1996; Lock, Young, Service, & Chandler, 1990; Rollins, 2003; Tamis-LeMonda, Bornstein, & Baumwell, 2001). Caregivers interpret behaviors as though they are meaningful and communicative, and respond accordingly, which provides translation and conversational structure that support childrens’ language development (Bates, 1979; Carpendale & Lewis, 2004; Desrochers et al., 1995; Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007; Masur, 1982). What has

not been examined specifically, however, are contingent responses to infants' communicative behaviors and the role they play in infants' development of the ability to initiate and respond to social interaction (but see Paavola et al., 2005a; Paavola et al., 2005b; Rollins, 2003).

The current study proposes that social responses to converging directed vocalizations with eye gaze facilitate vocal pragmatic development (i.e., vocal usage) in addition to other communicative gestures, as has been shown for vocal development and socially directed vocalizations (Goldstein et al., 2003; Goldstein & Schwade, 2008; Gros-Louis, West, & King, submitted). This study explored moment-to-moment interactions to examine the relationship among infants' vocal production, attentional focus, and maternal responses, and the relation these variables have to infants' communicative abilities in structured interactions with an experimenter. Infants' attentional state while vocalizing was considered because infants ultimately need to communicate concurrently with eye gaze through joint engagement episodes for shared communication in joint action to occur (Bruner, 1977; Carpenter, Nagell, & Tomasello, 1998) and because the combination of these behaviors is often seen as more sophisticated than simply a gesture or vocalization emitted alone (Bates, 1976). In addition, the pragmatic function of early communicative behaviors emerges through the concurrent use of eye gaze, vocalizations, and gestures (Bates, 1976; Golinkoff, 1986; Ninio & Snow, 1996).

The main goal of this study was to examine the relationship between mothers' responsiveness to infants' prelinguistic vocalizations and infants' own social communicative abilities as assessed by the ESCS (Mundy, et al., 2003). In addition, the possible association between infants' own communicative acts in free play with their mothers and their social communicative skills during the ESCS was examined, based on previous findings suggesting infants' behavior in one context, assessment or free play, influences their performance in the other (Paavola et al., 2005a; Paavola et al., 2005b). Lastly, the relationship between infants' communicative behavior during free play and

the ESCS contexts was assessed to determine how they are related to later vocabulary comprehension and production via the MacArthur Communicative Developmental Inventory: Words and Gestures (MCDI).

METHODS

Twenty, 13-month-olds (10 males) were recruited through Johnson County birth records or the Child Volunteer Registry in the Psychology Department at the University of Iowa. Participants were scheduled within 1 week of their 13-month birth date. Participants were predominantly Caucasian (n=17), 2 were Asian Islander and 1 was Mexican. Children were from middle-class, English-speaking households. All mothers and fathers (except for 2 mothers) had some college education. Demographic information can be found in Table D1. Two participants were excluded from data analysis because 1 did not return the MacArthur Communicative Development Inventory (MCDI) and the other was determined to be an outlier because the mother never responded to any of her infant's vocalizations during free play.

Infants visited the lab with their mothers. They first participated in structured interactions with the experimenter using the ESCS procedure (Mundy et al., 2003) and then played in unstructured interactions with their mothers for fifteen minutes.

The ESCS consists of a series of structured tasks to elicit nonverbal communication through initiative and responsive behaviors. This was administered using the objects and procedures as indicated in the ESCS manual (see Mundy et al., 2003 for an overview; see Appendix A for a summary of coded behaviors). According to the assessment procedures, four posters were located on the walls during the session: to the right and left of the infant, at 90° and 165° behind the infants' shoulders. During the assessment, infants were seated on their mothers' lap facing the experimenter across a table.

The ESCS procedure was followed by a fifteen-minute free play session in a large playroom with age appropriate toys (a school bus, barn with animals, barn with shapes, books, ring stacker, etc.). Mothers were told to play with their infant as they would at home.

Interactions during the ESCS assessment were recorded using two wall-mounted video cameras (Sony EVI-D100) and free play was recorded using three cameras, routed through an audio-video mixer (Datavideo SE-800AVK) to allow for selection of the best camera angle or picture-in-picture recording to determine infants' and mothers' attentional foci. Audio recordings were made using a wireless microphone (Sennheiser ew112G2) sewn into overalls worn by the infant throughout the entire visit.

At the time of the study, participants filled out a demographic questionnaire. When infants were fifteen months old, parents filled out the MCDI to measure infants' gesture production and production and comprehension vocabulary.

CODING

All coding was done using the EUDICO Linguistic Annotator (ELAN; http://www.lat-mpi.eu/tools/elan/), a free software program that allows for user-designed behavioral coding that is time locked with the video data. ESCS behaviors were coded following definitions provided by the ESCS manual and can be found in Appendix A (Mundy et al., 2003). In addition, vocalizations were coded that occurred during the administration of the ESCS because this study focused on vocalizations as a communicative act. At such a young age when a vocalization is paired with a gesture or eye gaze, these communicative acts are considered to be more complex compared to a gesture or eye gaze alone (Bates, 1976). The author and two research assistants coded the ESCS procedure. All discrepancies were discussed, reviewed, and re-coded; interobserver reliability was above 90%.

An additional primary coder coded the free play sessions for infant vocal behavior and maternal responses. The coder had been trained to ninety-five percent agreement for a previous related study examining caregiver responsiveness to prelinguistic vocalizations. Vocalizations included any sound that infants produced except negative vocalizations (e.g., fusses and cries), vegetative sounds (e.g., hiccups, burps), and effort sounds (e.g., grunts). Vocalizations that occurred in bouts with perceivable silence in between were coded as separate vocalizations. When a vocalization occurred, the direction of infants' visual gaze was noted. Vocal directedness categories included: 1) object-directed (DO); 2) caregiver-directed (DC); 3) alternating eye gaze from object to caregiver or vice versa (DOC); 4) not directed (i.e., infant was gazing around the room, not focused on anything; ND). Maternal responses were behaviors that occurred within 2 seconds of an infants' vocalization. These responses were as classified as related to infants' attentional focus or behavior (sensitive, "follow-in"-Tomasello & Farrar, 1986; SR), or unrelated to infants' focus or behavior, such as commenting on or acting on a

different toy (directive-Tomasello & Farrar, 1986; RR). Mothers' responses were further classified as behavioral (SB-act on toy), verbal (SV-comment on toy or to the infant), or a combination of behavioral and verbal response (SVB; see Appendix B for definitions of each).

Free play sessions were further coded by an additional primary coder after being trained by the author, using the coding scheme from the ESCS (with some modifications) to explore a coding scheme for free play interactions to quantify childrens' social communicative abilities. Definitions that were used for the coding of the free play with ESCS-like definitions can be found in Appendix C. There were adjustments made as necessary to the coding scheme, one such change being that all maternal initiative acts were coded to examine the number of times a child succeeded in producing a responsive act. This coding scheme is titled Free Play Social Communication (FPSC) and is referred to as such in the results and discussion that follow.

DATA ANALYSES

Student t-tests were performed to examine possible gender effects by comparing means for male and female infants. There were no group differences found in the free play or ESCS data. Therefore, data for male and female infants were pooled. Female infants had only marginally significant higher scores on the MCDI for total gestures and comprehension and production of words.

For free play behaviors, both infants' vocalizations and mothers' responses, proportions of each variable were used in analyses; frequency of these would not accurately capture the differences among mother-infant dyads because mothers only have the opportunity to respond based on the number of times their infant vocalizes. Vocalization categories of caregiver-directed (DC) or those combined with a shift in eye gaze from caregiver to object, or vice versa (DOC), were collapsed due to their infrequent occurrences and because they both involved visual attention directed towards mothers. Variables were all tested for normality and infants' directed vocalizations during free play as well as mothers' responses were found to have non-normal distributions. Therefore, arcsin square root transformations were performed on these proportion variables prior to analysis. Non-normally distributed ESCS and FPSC outcomes, which were used in predicting MCDI scores, were log transformed.

Pearson product-moment correlations were conducted to examine relationships between ESCS outcomes and free play behaviors, MCDI scores and ESCS outcomes, MCDI scores and free play behaviors, FPSC outcomes and ESCS outcomes, FPSC outcomes and free play behaviors, and FPSC outcomes and MCDI scores.

Multiple-step hierarchical regression analyses were conducted to examine predictive relationships among the variables in predicting ESCS outcomes and MCDI scores. Independent variables were entered into the model based on their level of

significance, with the most significant being entered first. In addition, some variables approaching significance were added as independents.

RESULTS

Descriptive Statistics

Infants' vocalizations during free play were primarily directed to objects (DO; 0.81 ± 0.18; average number of vocalizations per infant was 46.22). Mothers responded on average to seventy percent of infants' vocalizations (0.70 ± 0.25; average number of responses per mother was 32.56). Most mothers responded to a majority of their infants' vocalizations, with only 4 mothers responding to less than 50% of their infants' vocal acts. Mothers most often responded to their infants' vocalizations with sensitive responses (SR; 0.82 ± 0.23; average number of sensitive responses per mother was 27.89), which were primarily sensitive vocal responses (SV; 0.58 ± 0.28). Proportional frequencies of infants' specific directed vocalizations and mothers' responding can be found in Table D2.

Infants' outcomes from the ESCS assessment are presented in Table D3, MCDI scores in Table D4, and FPSC outcomes in Table D5.

ESCS and free play interactions

Infants' vocal production and mothers' responsiveness to vocalizations were both related to infants' scores on the ESCS assessment (Table D6). The following were the highest correlations found for free play behaviors and ESCS outcomes: 1) Number of vocalizations produced during ESCS and mothers' total responses to free play vocalizations (R; $r = -0.599$, $p = 0.009$); 2) Responding to Joint Attention scores (RJA) and mothers' responses to infants' directed to object vocalizations (R to DO; $r = -0.484$, $p = 0.042$); 3) Initiating Social Interaction scores (ISI) and infants' vocalizations with eye gaze alternation to object and caregiver (DOC; $r = 0.565$, $p = 0.015$); 4) Responding to Social Interaction scores (RSI) and mothers' sensitive behavioral responses to infants' vocalizations (SB to vocalizations; $r = 0.592$, $p = 0.010$).

A multiple-step hierarchical regression was done to more closely examine the relationships between the outcome measures on the ESCS and the behaviors in free play (Table D7). Maternal responses to infants' directed to object vocalizations (R to DO) and mothers' sensitive behavioral responses to infants' vocalizations with a shift in eye gaze from object to caregiver (SB to DOC) made significant contributions ($p = 0.06$; $p = 0.015$, respectively) predicting the total number of vocalizations produced with ESCS coded behaviors, based on the standardized coefficients (β) and variance explained (52.6%); however, when not directed vocalizations (ND) were also included in the model, an additional 3.3% of the variance was explained, with the model accounting for 55.9% of the variance in vocalizations produced during the ESCS (adjusted R square = 0.637).

For predicting Responding to Joint Attention scores (RJA), infants' vocalizations with a shift in eye gaze from object to caregiver (DOC) made a significant contribution ($p = 0.05$); together though, the three independent variables of mothers' total responses to directed to object vocalizations (R to DO), mothers' sensitive vocal-behavioral responses to infants' vocalizations paired with a shift in eye gaze between an object and caregiver (SVB to DOC), and infants' vocalizations paired with a shift in eye gaze from object to caregiver (DOC) accounted for 38.5% of the variance for Responding to Joint Attention scores (adjusted R square = 0.385). Sensitive vocal responses to infants' directed to object vocalizations (SV to DO) alone significantly predicted Responding to Social Interaction scores (RSI; $p = 0.022$).

In predicting Initiating Behavioral Request scores (IBR), mothers' overall responsiveness to vocalizations (R), standardized coefficients approached significance ($p = 0.056$) and accounted for 21% of the variance (adjusted R square = 0.161). The independent variable of infants' vocalizations paired with a shift in eye gaze between an object and caregiver (DOC) alone significantly predicted Initiating Social Interaction scores (ISI; $p = 0.015$).

Overall, the predictive relationships shown for the ESCS outcomes suggest that when mothers respond to directed to object vocalizations (DO; the most frequent type of vocalization) infants are not learning about how their communication is facilitative. In other words, too many responses to any vocalization the infant produces are not informative and infants are not capable of abstracting any meaning from these back-and-forth interactions. The relationship shown between infants' Initiating Social Interaction scores (ISI) and vocalizations paired with a shift in eye gaze between an object and caregiver (DOC) suggests the opportunity to use such types of behavior in free play observations to examine instances of initiating social interaction.

MCDI, free play interactions, and ESCS scores

There was no overall relationship between words comprehended or produced and ESCS outcomes (all p's > 0.05), although these vocabulary measures have previously been shown to be correlated with certain outcomes on the ESCS (Markus et al., 2000; Mundy et al., 1995; Mundy & Gomes, 1998; Mundy et al., 2007; Paavola et al., 2005a; Paavola et al., 2005b). Responding to Behavioral Request scores (RBR), however, were positively related to total words, nouns, and adjectives comprehended, as well as number of verbs produced ($r = 0.497$, $p = 0.036$; $r = 0.0471$, $p = 0.048$; $r = 0.674$, $p = 0.002$; $r = 0.472$, $p = 0.048$; respectively; see Table D8 for a complete listing of ESCS and MCDI correlations).

Very few relationships were found among infants' vocalizations, maternal responses, and MCDI scores (see Table D9). A multiple-step hierarchical regression was performed to predict MCDI scores based on the relationships observed between MCDI scores and free play interactions, and MCDI scores and ESCS outcomes (Table D10).

Responding to Joint Attention scores (RJA) accounted for 35.6% of the variance for the total number of Gestures Produced as measured by the MCDI, making a significant contribution to the model ($p = 0.007$). Responding to Behavioral Request

outcomes (RBR) accounted for 28.5% of the variance for the number of Verbs Produced and made a significant contribution to the model ($p = 0.016$). The number of vocalizations produced by the infant during free play made a significant contribution to the model predicting the number of Words Produced ($p = 0.040$), accounting for 15.9% of the variance, and for Adjectives Produced ($p = 0.041$), accounting for 18.9% of the variance.

These results suggest that infants' own behaviors during free play and the ESCS assessment are contributing to their later language abilities.

FPSC and ESCS

Correlation analyses revealed some important relationships between the ESCS assessment and the coding of free play interactions using the modified ESCS coding (shown in Table D11). Coding vocalizations when they occurred in combination with Initiating Joint Attention (IJA) behaviors correlated highly in both contexts ($r = 0.820$, $p > 0.001$). There was also a strong relationship between IJA vocalizations in both contexts and all vocalizations coded in combination with a social communicative behavior (IJA vocalizations-FPSC and ESCS vocalizations: $r = 0.494$; $p = 0.037$; IJA vocalizations-ESCS and FPSC vocalizations: $r = 0.619$, $p = 0.006$). These results suggest that, if vocalizations are considered, free play may be used to asses infants' baseline IJA abilities.

FPSC and free play

Vocalizations that were coded in combination with initiative or responsive joint attention behaviors during free play were found to be highly correlated with infants' vocalizations paired with a shift in eye gaze from mother to object (DOC; $r = 0.574$, $p = 0.013$). Vocalizations coded in combination with a social communicative act (all vocalizations coded during the FPSC were only identified if they occurred along with another communicative gestural/behavioral act) were found to be significantly negatively

correlated with infants' directed to object vocalizations (DO; r = -0.586, p = 0.011). These correlations are all shown in Table D12.

Initiating Behavioral Request scores (IBR) showed a negative correlation with Directed to Object vocalizations (DO; r = -0.484, p = 0.042), and Initiating Joint Attention scores (IJA) showed a similar trend with Directed to Object vocalizations (DO), though not significant (r = -0.411, p = 0.090). This suggests that DO vocalizations are inversely related to an infant's ability to initiate social interactions with a partner.

FPSC and MCDI

Correlation analyses, shown in Table D13, revealed that vocalizations produced in combination with an Initiating Joint Attention behaviors (IJA) were positively correlated with number of Words Produced, Verbs Produced, and Adjectives Produced (r = 0.499, p = 0.035; r = 0.481, p = 0.043; r = 0.600, p = 0.008; respectively).

Additionally, vocalizations produced in combination with Responding to Social Interaction behaviors (RSI) were found to be significantly negatively correlated with Total Gestures Produced (r = -0.480, p = 0.044). This suggests that those infants who are using vocalizations in combination with responsive behavior in social interactions are using fewer gestures overall.

To further examine the predictive validity of these relationships, a multiple-step hierarchical regression was performed, shown in Table D14. IJA vocalizations were shown to reliably predict both number of Words and Adjectives Produced, accounting for 27.7% and 49.6% of the variance, respectively (p = 0.014; p = 0.001; respectively). IJA vocalizations also approached significance for predicting both Verbs Comprehended and Produced. This indicates a strong relationship between using vocalizations combined with initiative joint attention acts with a social partner and later language abilities. In addition, RSI skills combined with a vocalization inversely predicted the number of Gestures Produced accounting for 18.2% of the variance (p = 0.044). If children are using

their vocalizations in combination with a responsive behavior to interact with a social partner, their gestures do not need to be as sophisticated because the vocalizations are helping support their meaning in interactions with more subtle gestures (Rowe & Goldin-Meadow, 2009).

DISCUSSION

Maternal responsiveness and ESCS vocalizations

The results of the current study suggest that both infant production of directed vocalizations (to caregivers and objects) and maternal contingent sensitive responses to directed vocalizations contribute to the emergence of communicative development. These findings are similar to the role maternal responsiveness has been shown to have in shaping vocal development (e.g., Goldstein & Schwade, 2008). Multiple-step hierarchical regression analyses revealed that mothers' responses to infants' object-directed vocalizations (R to DO) in free play inversely predicted the amount of vocalizations infants produced in combination with nonverbal communicative behaviors in structured ESCS interactions. This suggests that high overall responsiveness (i.e., any response to the most common type of vocalization made by the infant-DO) may not teach infants about the communicative function of their vocalizations, which is why these children do not vocalize as much in combination with other nonverbal gestural communicative acts during the ESCS. If mothers are responding to almost every vocalization the infant produces, rather than differentially responding to some, they are not learning about the relative effectiveness of vocalizations in combination with other communicative behaviors. Therefore, it is possible that these infants are less likely to produce vocalizations along with the interactive gestures during the ESCS because they have not learned about the effectiveness of vocal acts.

In contrast to the negative relationship between overall responsiveness to DO vocalizations and ESCS vocalizations, mothers' actions on objects that infants vocalized to while alternating eye gaze between their mothers and the object (SB to DOC) were predictive of infants' use of vocalizations during the ESCS. Maternal behavioral responses (actions that infants can visually witness occurring), in response to infants making a vocalization paired with eye gaze to a toy and their mother (SB to DOC), may

facilitate the relationship between appropriate eye contact when communicating because infants receive an observable reaction from their mothers. Furthermore, responses are informative about the effectiveness of vocalizations in influencing the behavior of social partners.

Maternal responsiveness and responsive ESCS outcomes

Responsive interactive behaviors on the ESCS, specifically RJA and RSI, were inversely predicted by maternal responses to object-directed vocalizations (R to DO), particularly sensitive verbal responses (SV to DO). A SV to DO alone, without acting on the object the infant is vocalizing to, may not further engage the child in social interaction because their attention is already focused on the toy.

Maternal responsiveness and initiative ESCS outcomes

Initiative behaviors during the ESCS were correlated with infants' own vocalizations in free play, including both DOC and DO vocalizations. Specifically, ISI outcomes were predicted by DOC vocalizations; DOC vocalizations were shown to be a trend in predicting IJA scores as well. These types of vocalizations that include a shift in eye gaze between mothers and objects (DOC) more resemble initiative behaviors in comparison to the responsive behaviors assessed by the ESCS. In regards to initiative-type interactions performed by the infant, DOC vocalizations represent more advanced initiative behaviors, which may correspond with earlier engagement behaviors such as social smiling and mutual gaze (Adamson & Bakeman, 1985). The relationship between initiating social interaction (ISI) on the ESCS and vocalizations with eye gaze alternation between object and caregiver in free play (DOC) suggest that these vocalizations could be used as a measure of initiative communicative behavior. Unlike language measures, pragmatic development is difficult to assess without the use of structured assessments or parent questionnaires with open-ended, qualitative questions (e.g., The Pragmatics Profile of Everyday Communication Skills in Children; Dewart & Summers, 1995). Because

DOC vocalizations (vocalizations paired with a shift in eye gaze) are so closely related to instances of ISI and IJA, DOC vocalizations in free play present a possible measure to examine infants' prelinguistic pragmatic skills in social interactions and could potentially be used in the future to determine a child's initiative interaction abilities (Adamson & Bakeman, 1991; Mundy et al., 2007).

ESCS outcomes and MCDI scores

Results from the multiple-step hierarchical regression examining later language abilities at 15 months revealed some relationships between responsive interactive behaviors on the ESCS and MCDI scores. The ability to respond to joint attention (RJA) predicted total Gesture Production and the skill of responding to a behavioral request (RBR) predicted number of Verbs Produced. These results suggest that the ability to respond to others' initiative communicative acts and follow others' attention and commands are related to later gesture production and some language production, whereas initiative abilities (at least as assessed by the ESCS) do not seem to play a role as there was no predictive relationship found for initiative ESCS outcomes on MCDI scores. However, from the free play interactions it was shown that the number of free play vocalizations a child produced positively predicted both Words Produced and Adjectives Produced.

FPSC outcomes and ESCS outcomes

The results from assessing the free play session using the ESCS coding scheme (FPSC) indicate the possibility of using a coding scheme like the one proposed here to examine social cognitive abilities in free play, under more typical situations. The correlations between the FPSC and other behaviors in the study indicate that there are some relationships to be revealed through coding free play interactions in such a way. This coding mainly showed that there is a significant relationship between vocalizations

that occur in combination with IBR, IJA, and RSI that need to be considered when examining free play interactions using such a scheme.

General Discussion

Using a purely behavioral assessment to examine infants' initiative and responsive interactions, especially at the age examined, may not be enough to uncover the mechanism by which individual differences in social communicative abilities are developing. As this study shows, infants are influencing their own behaviors across contexts, but there are not a lot of causal relationships found when maternal responsiveness is examined. Results of this study are consistent with those of Paavola and colleagues (2005a, 2005b), who found a relationship between specific types of maternal responses including: yes/no questions, descriptions of things, commands/warnings, social play talk, naming of objects and people, and fillers, all predicted infants' behaviors during free play as well as their performance on the Communication and Symbolic Behavior Scales, an assessment similar to the ESCS (CSBS; Paavola et al., 2005a; Paavola et al., 2005b; see Wetherby & Rodriguez, 1992 for a description of the CSBS procedure); however, one main difference between Paavola et al.'s studies and the current study is that they examined maternal responses to all infant behaviors during free play, whereas this study focused exclusively on maternal responses to infants' vocalizations because infants must bring together vocalizations with eye gaze for more complex communicative behavior. In fact, eye gaze alternation paired with other communicative behaviors is often considered an indication of intentional communication (Bates, 1976; Bates et al., 1979). For example, eye gaze helps mothers interpret intentions of their preverbal children (Golinkoff, 1986) and, furthermore, studies of toddler-mother communication indicate that children's use of eye contact with speech indicates that an utterance is socially intended and directed to a specific person (Schieffelin, 1983).

The relationships observed in the current study show that maternal responses to vocalizations and infants' own vocalizations during free play are related to their behavior during assessment of social communicative abilities. One interpretation of this finding is that infants' behavior is consistent across settings with different social partners, mothers and strangers (Paavola et al., 2005a; Paavola et al., 2005b). Another explanation may be that mothers, through prior contingent responding, have facilitated infants' use of eye gaze with vocalizations. Vocalizations occurring concurrently with attentional focus on an object initially are coincidences rather than being under voluntary control (cf., Collis, 1979). And, although it is debated whether infants are truly 'communicating' on the grounds that they may not 'intend' to convey a message (Grice, 1957; Searle, 1969), the vocalizations elicit responses from caregivers (Bates et al., 1975; Locke, 1996); caregivers interpret vocalizations as though they are meaningful and communicative (see e.g., Bates, 1979; Carpendale & Lewis, 2004; Desrochers et al., 1995; Lock, 1990; Vygotsky, 1978). By commenting on or manipulating the object that the infant is focused on when they vocalize, caregivers can shape the development of behaviors as infants learn the relationship between vocalizing and its functional outcome (Bruner, 1975; Collis, 1979; Halliday, 1979; Siegel, 1999). The results of this study suggest that infants' pragmatic communicative abilities emerge through the social interactions in which they are embedded through the interaction of infants' communicative behaviors and maternal responses to them (see also Gros-Louis, et al., submitted).

A secondary finding from this study is the identification of a social function for directed vocalizations in caregiver-infant interactions in the absence of gestures, prior to the onset of language. Although vocalizations occur in social interactions long before the emergence of gestures and can influence maternal behavior (cf., Bloom, D'Odorico, & Beaumont, 1993; Gros-Louis, West, Goldstein, & King, 2006; Papousek, Papousek, & Bornstein, 1985), few studies examine the prelinguistic usage of vocalizations or their communicative function in isolation. The role of vocalizations in social communicative

behaviors are typically not focused on until the second year when toddlers produce their first words or word approximations (e.g., "conventionalized acts"-Bakeman & Adamson, 1986; "verbalizations"-Carpenter, Pennington, & Rogers, 2002; Iverson, Capirci, Volterra, & Goldin-Meadow, 2008; "speech acts"-Dore, 1974; but see Ninio & Bruner, 1978). Traditionally, prelinguistic social communicative behaviors have been identified as *nonverbal* pragmatic skills, largely focusing on gestures and eye gaze alternation to identify the function or meaning of the behaviors (see Striano, 2001 for an overview). Furthermore, longitudinal studies have documented the integration of vocalizations with gestures over time as they relate to changing communicative abilities (Bates, Thal, Whitesell, Fenson, & Oakes, 1989; Bruner, 1977; Goldin-Meadow, 1998; Messinger & Fogel, 1998). Thus, the anchor behavior of interest is gestures and how they come together with vocalizations and eye gaze, rather than considering vocalizations alone or vocalizations in combination with eye gaze. When taken together, the current results suggest the need to consider the communicative potential of prelinguistic vocalizations, in combination with eye gaze, in social interactions.

One limitation of the current study is that maternal responsiveness and infants' communicative behaviors in the ESCS were measured at the same time point. Naturalistic studies of prelinguistic communication have documented increasingly complex communicative behavior between the ages of nine to 12 months. (e.g., Bates et al., 1975; Bates, 1976; Dore, 1974; Ninio & Bruner, 1978). Therefore, 13-month-olds in this study may have already developed multimodal social communicative behaviors. Maternal responsiveness still plays an important role here, but infants' behavior may have already been influenced by maternal responsiveness (or other factors) earlier in development rather than in the moment. Therefore, there is a relationship between maternal responsiveness and infant behavior, but it is not as strong as one might see if they were to examine the relationship between maternal responsiveness in free play at an earlier age and the ESCS at 13 months of age. Ideally, one would want to examine the mother-infant

interaction at 9 months of age and assess their social communicative skills around 13-15 months of age to examine predictive relationships between earlier interactions and later emerging skills.

The results of this study suggest a dynamic, interactive process in the development of prelinguistic communicative behavior mediated by infant directed vocalizations and maternal responsiveness which could be further explored if contingent interactions were examined earlier in development. These results provide support, and a potential mechanism, for the gradual emergence of social communicative behavior (Striano, 2001) in contrast to more cognitive views of communicative development, involving the understanding of others as intentional agents (cf., Tomasello, 1995; Tomasello et al., 2005). In addition, this study has identified a source of variability in infants' prelinguistic communicative skill, resulting from maternal responsiveness. Just as gestures elicit verbal responses and 'translations' from caregivers (Goldin-Meadow et al., 2007; Kishimoto, Shizawa, Yasuda, Hinobayashi, & Minami, 2007), prelinguistic directed vocalizations elicit variable responses from mothers. Future studies should examine the emergence of contingent responding from mothers to their infants' vocalizations to assess which behaviors play a role in later social communicative abilities of infants.

APPENDIX A DESCRIPTIONS OF THE EARLY SOCIAL COMMUNICATIVE SCALES (AFTER MUNDY ET AL., 2003)

Initiating Behavioral Request (IBR): 1) Makes eye contact with experimenter after a toy has stopped moving or has been put out of reach; 2) reaches with or without eye contact to the experimenter to an object out of reach; 3) points with or without eye contact with experimenter to an object that has stopped moving or has been put out of reach; 4) gives a toy to the experimenter with or without making eye contact

Initiates Joint Attention (IJA): 1) Makes eye contact with experimenter while manipulating the toy; 2) makes alternate gaze from moving toy and experimenter's eyes; 3) points with or without eye contact to the experimenter, to an active toy, or to a distal object in the experimental room; 4) shows a toy to the experimenter by holding it up to their face; 5) makes a bid to their caregiver for their attention or help

Initiating Social Interaction (ISI): 1) initiates turn taking with the experimenter by being the first to roll the object to the other; 2) performs a tease (unwanted act) with or without smiling and eye contact

Responding to Behavioral Request (RBR): Proportion of times an infant is successful at responding to a request made by the experimenter to give them back an object

Responding to Joint Attention (RJA): Number of trials infant is successful in: 1) following the point of the experimenter to pictures in a book; 2) following the line of regard (left, back left, right, back right) of the experimenter's point and eye gaze

Responding to Social Interaction (RSI): 1) makes eye contact with the experimenter after or during an interaction initiated by the experiment (if during, must be a duration of at least 5 seconds); 2) produce an act of excitement or acknowledgement with or without eye contact after an interaction initiated by the experimenter; 3) returns the pass of rolling an object back and forth between the infant and experimenter; 4) uses objects appropriately after the experimenter initiates an interaction with the object

APENDIX B DESCRIPTION OF INFANTS' AND MOTHERS' FREE PLAY CODED BEHAVIORS

Infants' vocalizations:

Directed to Object (DO): Infants gaze at an object when vocalizing

Directed to Caregiver (DC): Infants gaze at mother when vocalizing

Directed to Object then Caregiver OR Caregiver then Object (DOC): Infants gaze shift from object/mother to the other when vocalizing

Not Directed (ND): Infants look around the room, not focused on anything when vocalizing

*DC and DOC were combined due to their infrequency and similar attentional state of engaging their mother through eye gaze

Mothers' responses:

Responds to Vocalization (R): Mother responds to the vocalization (further classified as follows):

- Redirective Response to Vocalizations (RR): Mother responds by commenting or acting on something the infant is not focused on
- Sensitive Response to Vocalizations (SR): Mother responds by following the infants' attentional focus (further classified as follows):
  - Sensitive Behavior (SB): Mother acts on the object that the infant is focused on when the infant vocalizes
  - Sensitive Vocalization (SV): Mother comments on the object that the infant is focused on when the infant vocalizes
  - Sensitive Vocalization and Behavior (SVB): Mother responds with both a behavior and comment on the object that the infant is focused on when the infant vocalizes

APPENDIX C FREE PLAY SOCIAL COMMUNICATION (FPSC) DEFINITIONS ASSESSED USING EARLY SOCIAL COMMUNICATION SCALES (ESCS) CODING SCHEME

While coding we are looking at instances of Joint Attention, Behavioral Requests, and Social Interaction

General Rules:

1. If a gesture is not well-defined, do not rate it
2. If there is confusion whether a behavior should be considered Joint Attention or Behavioral Request, default to Behavioral Request
3. Do not code behavior that is obscured
4. If the behavior changes, rate the highest level of behavior
5. Mothers' initiative acts need to be coded so as to get an accurate account of infants' abilities to respond to these acts (this is different from the ESCS procedure because an experimenter's acts can be controlled, whereas mothers' in the free play context cannot be)
    a. Any behavior on the part of the mother that is a continuation or repetition of a previous act is not coded (therefore, the infant does not get coded on passing/failing at RBR, RSI, or RJA), infants must have enough time to react (we have given them a 2 second window to do so)
        i. The exception to this rule is when there is a switch from a RSI to an RBR because these are 2 completely different types of initiative acts on the mother's part
    b. Mothers will occasionally 'tidy-up' the toys or organize toys, moving them all around. These acts will not be counted as initiative by the mother in that she is not doing this for the purpose of getting the infant's attention or wanting them to respond. Similarly, mothers moving other objects out of the way to get to a target object are NOT an initiation with regard to the object that is moved. Infant looking at the object that is moved is not coded, but infant looking at target object IS
6. Different than the ESCS (original): we have to code when infants fail at measures of RJA and RSI (in addition to the RBR) to get a proportion of scores, in order to compare them to other infants. Unlike during the ESCS assessment, in free play we cannot control the number of times mothers make initiating interactions, either through joint attention or social interaction
7. In addition, there is more likely in free play going to be more opportunities for responding to JA or SI because this is not an assessment and mothers will most likely be trying to engage their child during free play, not "testing" them

Joint Attention

Initiated Joint Attention (IJA)

Eye Contact

- The child makes eye contact with their mother while manipulating or touching an **inactive** toy. Child must be touching the object
- If child is not touching the object, but it is the center of conversation or focus **of the child** at that moment, label IBR-Eye Contact
- Do not code if this is elicited by the mother - the child must voluntarily make eye contact with the mother without her doing something to grab their attention

Alternate

- The child alternates looking between an **active** object (the balls spinning inside the top toy) and the mothers' eyes (must go from toy → mothers' eyes). Code each of these as one instance of alternate

Point

- A clear articulation of the index finger; point to an **active** toy (the balls spinning inside the top toy), pictures in a book, animals on the walls, or pictures on toys
- This may occur with eye contact with mom and should be coded as IJA Point and Eye Contact

Show **to face**

- The child raises a toy upward toward their mothers' face while looking at her (object still for 2 seconds, unless taken away by mother)
    - If she interprets this as give and takes it and the child seems content with this, label as IBR give and eye contact

Responding to Joint Attention (RJA)

Following Proximal Point

- At any point, if mom points to an object or a picture (in a book or on the wall) and the infant follows by immediately turning head and eyes
    - If mothers influences by repeating more than once to look (ex. John look at that, hey look over at that, look)…do not code as anything

Behavioral Requests

Initiating Behavioral Requests

Eye Contact

- The child makes eye contact with their mother with an **inactive** object that seems to be the focus of attention or conversation between them
    - Child cannot be touching the toy (this would be IJA-Eye Contact), mother can be touching
- Possibly could occur after the balls bouncing become inactive, for example
- If there is turn-taking going on, only code Eye Contact before it begins
    - If it looks like a game is going on between mother and child, do not code for Eye Contact until a new task/toy is introduced
- Do not code if this is elicited by the mother

Reach

- The child extends their arm toward an **out of reach** object
    - This should ONLY be coded when an infant attempts to reach for an object and does not retrieve it. If they move closer after to reach for it, this is okay, but the initial reach being coded cannot be coded if they are successful in retrieving the toy

Appeal

- The child extends their arms toward an **out of reach object** while making eye contact with their mother
- Eye contact and reach must occur simultaneously at some point

Point

- The child uses an extended index finger to indicate the desire for an object or event (not pictures on walls, or at a picture on a toy)
- If occurs with eye contact, code as IBR Point and Eye Contact

Give **to mothers' hands or body**

- The child pushes, throws, or hands an object to his/her mother in order to request that they repeat an action with it or to get rid of it
    - If the child refuses to let it go after mom tries to take it, this should be coded as IJA show
- This may occur with eye contact and should be coded as IBR Give and Eye Contact

Responding to Behavioral Request

Follows Command

- If mother requests child to do something either with or without a gesture and waits for an action before repeating the request, code if the infant follows the request or not and whether or not mom was using a gesture or not (for example, palms up in requesting a toy or asking them to put the cookies in the jar and showing them an example first)
- This can also be coded if the mother says something like "look, John, look here" and the child looks to what she is talking about. If the mother is pointing however, that would coded as RJA Follows Point

Responding when their name is called

- Infant looks at mother/or toy if placed in their view after she has said their name

Point in Imitation

- The child points to an object or after having witnessed their mom point to something

Social Interaction

Initiating Social Interaction

Initiates turn taking

- Upon picking up or receiving a toy, the child initiates a game with the toy involving the mother, mother cannot perform the act first

Tease

- Low-level Tease: engaging in a prohibited act while making eye contact with their mother
- High-level Tease: engaging in a prohibited act while making eye contact with their mother and smiling

Responding to Social Interaction

- This behavior can be a response to mothers requesting attention to a part of a toy, the mother requesting attention to herself by singing, clapping, etc.

Eye Contact

- The child makes eye contact with their mother after they have been tickled or played with OR during if it is held for 2 or more seconds
- After mother has initiated some type of interaction vocally, behaviorally, or with a toy, the child makes eye contact with her

Act

- The child makes an excited response after being tickled or played with
- Can be vocal, gestural, or postural
- After mother has initiated some type of interaction vocally, behaviorally, or with a toy, the child acts on the toy or towards the mother in some way

Appeal

- The child produces an act with simultaneous Eye Contact
- After the mother has initiated some type of interaction vocally, behaviorally, or with a toy, the infant both looks at mom and interacts with the toy or her in some way

Responding to Turn-Taking

- If there is a game going on between mother and child, how many times the child returns with a response to continue the game

Vocal Coding

- Vowel (v) or Consonant (cv) and/or multiple syllable
- Either coded:
    - within an already coded ESCS behavior (excluding RBR or eye contact or alternate gaze that is not previously coded. For example, if eye contact occurs during RBR or during turn taking we have not previously coded this, it should therefore be coded as a voc w/ a gesture)
    - OR coded w/ gesture OR w/o gesture
        - a gesture will include any type of ESCS behavior, point, reach, eye contact, etc.
        - playing with a toy and vocalizing at it will not count as a gesture because this in no way exemplifies IJA or anything else
- If vocalizations can be broken down in to separate ‘words’, this should be done, unless it is clearly one long string (i.e., no audible silence in between; in this case UNLESS you hear a definite consonant it should be coded v, ms)

APPENDIX D: TABLES

Table D1. Means, standard deviations, and ranges for demographic variables

Demographic	M	SD	Range
Mothers' age	33.59	4.39	25 – 43
Fathers' age	35.18	5.2	29 – 49
English	All	--	--
Race	14 = white, 1 = Mexican, 2 = Asian Islander	--	--
Mothers' education	4.22	0.81	2 – 5
Fathers' education	4.65	1.00	3 – 6

For education 1= less than high school; 2 = high school diploma/GED; 3 = associates degree/some college; 4 = bachelors degree; 5 = masters degree; 6 = Ph.D./Professional

Table D2. Means, standard deviations, and ranges for variables of maternal responsiveness to infants' vocalizations and infant vocal behavior

Free Play Variable	M	SD	Range
Maternal Responses (average frequency = 32.56)			
R	0.70	0.25	0 – 1
SR	0.82	0.23	0 – 1
SB	0.07	0.10	0 – 0.33
SV	0.58	0.28	0 – 1
SVB	0.24	0.18	0 – 0.67
Infant Vocalizations (average frequency = 46.22)			
DO	0.81	0.18	0.29 – 1
DOC	0.14	0.17	0 – 0.71
ND	0.05	0.07	0 – 0.22

Note: Definitions for mothers' responsiveness and infants' vocalizations abbreviations can be found in Appendix B. Maternal responses and infants vocalizations are all reported as proportions of the total responses and total vocalizations during the session

Table D3. Means, standard deviations, and ranges for infants' ESCS scores and vocalizing during ESCS assessment

ESCS		M	SD	Range
ESCS				
	IBR	33.61	11.61	12 - 50
	IJA	25.56	12.53	9 - 59
	ISI	2.67	3.66	0 - 16
	RBR*	0.31	0.24	0 - 1
	RJA	8.50	2.79	2 - 12
	RSI	18.11	4.70	10 – 25
ESCS vocalizations				
	IBR	11.17	9.21	0 - 28
	IJA	4.83	6.03	0 - 23
	ISI	0.33	0.77	0 - 3
	RJA	0.44	0.51	0 - 1
	RSI	2.78	2.96	0 – 11
	Total	21.11	15.46	2 – 51

Note: Definitions for ESCS abbreviations can be found in Appendix A

*Infant vocalizations are not counted during RBR as this is coded as pass or fail

Table D4. Means, standard deviations, and ranges for infants' MCDI scores

MCDI Variable	M	SD	Range
Vocabulary Comprehension	131.44	81.22	8 - 360
Vocabulary Production	19.17	15.75	0 - 52
Total Gestures	34.28	9.50	10 - 53
Noun Comprehension	78.78	49.56	5 - 206
Noun Production	8.28	7.53	0 - 21
Verb Comprehension	18.06	12.00	1 - 51
Verb Production	0.94	1.73	0 - 6
Adjective Comprehension	7.50	8.54	0 - 37
Adjective Production	0.67	0.97	0 - 3

Table D5. Means, standard deviations, and ranges for infants' FPSC scores and vocalizing during the free play sessions coded with ESCS-like scheme.

FPSC		M	SD	Range
FPSC	IBR	9.11	6.66	2 - 29
	IJA	10.61	7.75	1 – 32
	RBR	0.58	0.17	0.33 - 1
	RJA	0.69	0.35	0 – 1
	RSI	0.83	0.09	0.68 - 0.95
FPSC vocalizations	IBR	3.67	5.14	0 - 20
	IJA	4.28	6.03	0 - 25
	RSI	4.94	4.78	1 - 21
	Total	13.78	12.78	2 – 41

Note: Definitions for FPSC abbreviations can be found in Appendix C

*Some FPSC variables were excluded from analyses because they did not occur frequently enough to include them

Table D6. Pearson product-moment correlations between infants' ESCS outcomes and infants' vocalizations and mothers' responsiveness during free play

	# ESCS Vocalizations	IBR	IJA	ISI	RJA	RSI
ND	0.413	0.295	-0.092	-0.187	0.127	-0.140
DO	0.038	0.038	-0.413	**-0.477***	0.333	-0.336
DOC	-.0163	-0.154	0.444	**0.565***	-0.417	0.397
R	**-0.599****	-0.459	0.099	0.138	-0.388	0.402
SR	-0.012	0.296	0.102	0.327	0.203	-0.325
SB	0.145	-0.021	-0.096	-0.092	0.100	**0.592****
SV	0.143	0.237	0.329	0.333	-0.116	**-0.520***
SVB	-0.142	-0.218	-0.192	-0.147	0.191	0.383
R to DO	**-0.543***	-0.401	0.189	0.229	**-0.484***	0.389
SR to DO	-0.148	0.040	0.095	0.381	-0.005	0.029
SB to Do	0.169	-0.051	-0.286	-0.240	0.209	**0.518***
SV to DO	0.205	0.272	0.394	0.379	-0.128	**-0.537***
SVB to DO	-0.116	-0.258	-0.298	-0.126	0.192	0.324
R to DOC	-0.044	-0.321	-0.110	0.143	-0.106	0.411
SR to DOC	0.244	0.108	0.189	0.257	0.023	0.238
SB to DOC	**0.540***	0.381	0.133	0.063	0.037	0.290
SV to DOC	0.110	-0.245	0.196	0.438	-0.383	0.047
SVB to DOC	-0.059	0.181	-0.025	-0.245	0.436	0.038

* $p < .05$, ** $p < .01$

Note: Definitions for mothers' responsiveness and infants' vocalizations abbreviations can be found in Appendix B

Table D7. Summary of multiple-step hierarchical regression analyses for infants' free play vocalizations and mothers' responsiveness predicting the ESCS scores

Dependent/independents analysis	B	SE B	β
ESCS vocalizations			
Step 1 adjusted $R^2 = 0.295$			
R to DO	-41.295	15.960	**-0.543***
Step 2 adjusted $R^2 = 0.581$			
R to DO	-40.968	12.700	**-0.539****
SB to DOC	21.798	6.804	**0.535****
RJA			
Step 1 adjusted $R^2 = 0.187$			
R to DO	-6.647	3.003	**-0.484***
ISI			
Step 1 adjusted $R^2 = 0.319$			
DOC	8.468	3.094	**0.565***
RSI			
Step 1 adjusted $R^2 = 0.243$			
SV to DO	-8.927	3.510	**-0.537***

* $p < .05$, ** $p < .01$

Note: Definitions for mothers' responsiveness and infants' vocalizations abbreviations can be found in Appendix B

Table D8. Pearson product-moment correlations between ESCS outcomes and MCDI scores

	Words Comp.	Words Prod.	Total Gestures	Nouns. Comp.	Nouns Prod.	Verbs Comp.	Verbs Prod.	Adj. Comp.	Adj. Prod.
# ESCS Vocalizations	-0.118	0.371	0.310	-0.101	0.417	-0.030	0.198	-0.283	0.336
IBR Vocalizations	-0.190	0.195	0.146	-0.151	0.240	-0.161	0.104	-0.319	0.099
IJA Vocalizations	0.106	0.426	0.457	0.044	0.374	0.350	0.292	-0.036	**0.493***
ISI Vocalizations	-0.244	-0.095	-0.022	-0.275	-0.088	-0.028	0.059	-0.198	0.158
RJA Vocalizations	-0.236	-0.026	0.094	-0.256	-0.065	-0.139	0.096	-0.243	0.198
RSI Vocalizations	-0.189	0.150	0.124	-0.169	0.272	-0.230	0.020	-0.205	0.075
IBR	-0.136	0.115	0.026	-0.118	0.102	-0.117	0.227	-0.095	0.108
IJA	-0.375	-0.039	-0.358	-0.395	-0.026	-0.232	0.020	-0.263	0.021
ISI	-0.310	-0.213	**-0.501***	-0.297	-0.203	-0.269	-0.105	-0.162	-0.050
RBR	**0.497***	0.220	0.214	**0.471***	0.143	0.394	**0.472***	**0.674****	0.252
RJA	0.335	0.359	**0.595****	0.295	0.304	0.435	0.298	0.251	0.369
RSI	0.197	0.158	0.072	.0209	0.210	0.081	0.088	0.130	0.125

* $p < .05$, ** $p < .01$

Note: Definitions for ESCS abbreviations can be found in Appendix A

* Comp.: Comprehend; Prod.: Produce; Adj.: Adjectives

Table D9. Pearson product-moment correlations between infants' vocalizations and mothers' responsiveness during free play and MCDI scores

	Words Comp.^	Words Prod.^	Total Gestures	Nouns Comp.^	Nouns Prod.^	Verbs Comp.^	Verbs Prod.^	Adj. Comp.^	Adj. Prod.^
ND	-0.104	0.153	0.065	-0.045	0.181	-0.238	-0.107	-0.211	-0.019
DO	0.296	0.100	0.440	0.299	0.108	0.277	0.028	0.227	0.032
DOC	-0.282	-0.173	**-0.510***	-0.310	-0.194	-0.206	0.014	-0.162	-0.027
Number of FP vocalizations	0.068	0.417	0.342	0.086	0.387	0.137	0.347	-0.046	**0.539***
R	0.207	-0.035	-0.202	0.214	0.014	0.081	-0.082	0.304	-0.189
SR	-0.045	-0.116	0.072	-0.084	-0.210	0.100	-0.002	0.018	0.128
SB	0.049	-0.056	0.030	0.050	0.027	0.029	-0.104	-0.140	-0.218
SV	-0.207	-0.043	-0.047	-0.190	-0.103	-0.211	-0.067	-0.017	0.087
SVB	0.284	0.058	0.104	0.243	0.062	0.368	0.151	0.118	0.055
R to DO	0.088	-0.096	-0.290	0.104	-0.041	-0.046	-0.140	0.211	-0.250
SR to DO	0.210	0.083	0.204	0.162	0.085	0.356	0.044	0.153	0.156
SB to DO	0.045	-0.148	0.097	0.031	-0.089	0.084	-0.168	-0.156	-0.201
SV to DO	-0.282	-0.075	-0.094	-0.264	-0.123	-0.277	-0.103	-0.096	0.034
SVB to DO	0.436	0.166	0.150	0.404	0.190	**0.484***	0.207	0.278	0.108

* $p < .05$, ** $p < .01$

Note: Definitions for mothers' responsiveness and infants' vocalizations abbreviations can be found in Appendix B

^ Comp.: Comprehend; Prod.: Produce; Adj.: Adjectives

Table D9. Continued

	Words Comp.^	Words Prod.^	Total Gestures	Nouns Comp.^	Nouns Prod.^	Verbs Comp.^	Verbs Prod.^	Adj. Comp.^	Adj. Prod.^
R to DOC	0.264	0.200	0.336	0.245	0.146	0.306	0.201	0.132	0.329
SR to DOC	0.194	0.337	0.293	0.196	0.269	0.198	0.333	0.099	0.378
SB to DOC	0.016	0.201	-0.031	0.058	0.308	-0.123	0.104	-0.032	-0.096
SV to DOC	0.269	0.433	0.130	0.291	0.376	0.239	0.280	0.199	**0.537***
SVB to DOC	-0.094	-0.209	0.215	-0.140	-0.295	0.026	0.016	-0.099	-0.063

* $p < .05$, ** $p < .01$

Note: Definitions for mothers' responsiveness and infants' vocalizations abbreviations can be found in Appendix B

^ Comp.: Comprehend; Prod.: Produce; Adj.: Adjectives

Table D10. Summary of multiple-step hierarchical regression analyses for free play interaction and ESCS scores predicting MCDI scores

Dependent/independents analysis	B	SE B	β
Words Produced			
Step 1 adjusted R^2 = -0.062			
IJA	-0.286	8.688	-0.008
Step 2 adjusted R^2 = 0.153			
IJA	-6.881	8.289	-0.198
Number of FP vocalizations	6.175	2.739	**0.538***
Gestures Produced			
Step 1 adjusted R^2 = 0.356			
RJA	2.255	0.719	**0.629****
Verbs Produced			
Step 1 adjusted R^2 = 0.285			
RBR	1.351	0.497	**0.574***
Adjectives Produced			
Step 1 adjusted R^2 = 0.189			
Number of FP vocalizations	0.338	0.151	**0.487***

* $p < .05$, ** $p < .01$

Note: Definitions for ESCS abbreviations can be found in Appendix A and mothers' responsiveness and infants' vocalizations abbreviations in Appendix B

Table D11. Pearson product-moment correlations between ESCS scores and FPSC scores

	FPSC								
	Vocalizations	IBR vocalizations	IJA vocalizations	RSI vocalizations	IBR	IJA	RBR	RSI	RJA
ESCS									
Vocalizations	0.181	0.316	**0.494***	-0.273	0.180	0.377	-0.206	0.139	-0.007
IBR vocalizations	0.061	0.287	0.315	-0.343	0.221	0.229	-0.312	0.064	-0.036
IJA vocalizations	**0.498***	**0.038***	**0.820****	-0.078	0.282	**0.645****	-0.114	0.250	-0.090
ISI vocalizations	0.206	0.015	0.208	0.134	-0.065	0.420	-0.459	0.145	0.241
RJA vocalizations	0.313	0.030	0.206	0.347	-0.292	-0.043	0.348	0.302	-0.189
RSI vocalizations	-0.211	-0.163	-0.131	-0.117	-0.076	-0.030	-0.081	0.225	0.230
IBR	0.184	0.284	0.336	-0.203	0.192	0.093	0.124	0.069	-0.052
IJA	**0.619****	0.144	0.340	**0.616****	0.097	0.418	0.054	0.063	0.142
ISI	0.437	-0.081	-0.033	**0.681****	-0.061	0.213	-0.056	0.114	0.430
RBR	-0.216	-0.077	-0.234	-0.073	0.175	-0.289	0.002	0.163	0.172
RJA	-0.055	0.324	0.425	**-0.487***	0.196	0.105	0.272	0.140	-0.255
RSI	-0.244	-0.424	-0.331	0.155	-0.361	-0.188	0.291	0.061	-0.100

* $p < .05$, ** $p < .01$

Note: Definitions for ESCS abbreviations can be found in Appendix A and FPSC abbreviations in Appendix C

Table D12. Pearson product-moment correlations between infants' vocalizations and mothers' responsiveness during free play and FPSC scores

	Vocalizations	IBR vocalizations	IJA vocalizations	RSI vocalizations	IBR	IJA	RBR	RJA	RSI
# FP vocs	**.527***	0.467	**.478***	0.290	0.367	0.413	-0.043	0.111	0.109
ND	0.148	**.473***	0.212	-0.233	**.532***	0.093	0.081	-0.067	-0.128
DO	**-.586***	-0.291	-0.217	**-.569***	**-.484***	-0.411	-0.112	0.368	-0.171
DOC	**.574***	0.154	0.175	**.674****	0.322	0.409	0.027	-0.391	0.264
R	-0.155	-0.367	-0.319	0.237	-0.311	-0.175	0.209	0.373	-0.146
SR	0.214	0.068	0.211	0.057	-0.146	0.040	0.103	-0.174	0.352
SB	-0.150	-0.212	-0.144	0.032	-0.209	-0.056	0.354	-0.408	0.372
SV	0.154	0.098	0.124	-0.002	-0.050	-0.049	-0.279	0.416	-0.099
SVB	0.135	0.097	0.129	0.165	0.168	0.251	0.295	-0.401	0.161
R to DO	-0.090	-0.311	-0.309	0.269	-0.232	-0.128	0.139	0.406	-0.152
SR to DO	0.217	0.016	0.167	0.173	-0.098	0.264	0.306	-0.223	**.504***
SB to DO	-0.308	-0.242	-0.155	-0.195	-0.273	-0.073	0.354	-0.463	0.347
SV to DO	0.230	0.159	0.146	0.064	0.022	-0.014	-0.255	0.381	-0.008
SVB to DO	0.043	0.018	0.100	0.089	0.062	0.248	0.178	-0.237	0.180
R to DOC	0.271	0.223	0.099	0.332	0.183	0.164	0.006	-0.230	0.316
SR to DOC	0.368	0.262	0.178	0.368	0.259	0.070	0.114	-0.125	0.369
SB to DOC	-0.042	-0.059	-0.057	0.007	0.101	0.011	-0.018	0.095	0.279
SV to DOC	0.258	0.042	0.237	0.200	-0.021	0.251	-0.283	0.120	-0.175
SVB to DOC	0.288	0.422	0.127	0.220	0.318	-0.110	0.404	-0.379	0.376

* $p < .05$, ** $p < .01$

Note: Definitions for mothers' responsiveness and infants' vocalizations abbreviations can be found in Appendix B and FPSC abbreviations in Appendix C

Table D13. Pearson product-moment correlations between MCDI scores and FPSC scores

	Vocalizations	IBR vocalizations	IJA vocalizations	RSI vocalizations	IBR	IJA	RBR	RJA	RSI
Words Comprehend	-.138	-.009	.186	-.307	.089	.124	.031	.298	-.090
Words Produced	.185	.205	**.499***	-.139	.245	.341	-.110	.181	-.130
Total Gestures	-.040	.385	.332	**-.480***	.162	.089	.014	.131	.394
Nouns Comprehend	-.174	-.031	.129	-.313	.054	.045	.061	.294	-.160
Nouns Produced	.094	.107	.394	-.143	.185	.310	-.072	.204	-.171
Verbs Comprehend	.028	.096	.417	-.282	.152	.412	-.064	.270	.062
Verbs Produced	.239	.077	**.481***	.056	.220	.406	-.362	.320	-.085
Adjectives Comprehend	-.112	-.074	.093	-.168	.123	.110	-.082	.418	-.058
Adjectives Produced	.316	.247	**.600****	-.042	.206	.459	-.253	.108	.054

* $p < .05$, ** $p < .01$

Note: Definitions for FPSC abbreviations can be found in Appendix C

Table D14. Summary of multiple-step hierarchical regression analyses for FPSC scores predicting MCDI scores

Dependent/independents analysis	B	SE B	β
Words Produced			
Step 1 adjusted $R^2 = 0.277$			
IJA vocalizations	21.781	7.945	**0.565***
Gestures Produced			
Step 1 adjusted $R^2 = 0.182$			
RSI vocalizations	-0.953	0.436	**-0.480***
Adjectives Produced			
Step 1 adjusted $R^2 = 0.496$			
IJA vocalizations	1.688	0.400	**0.725****

* $p < .05$, ** $p < .01$

Note: Definitions for FPSC abbreviations can be found in Appendix C

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