Infants’ prelinguistic communicative acts and maternal responses: Relations to linguistic development

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Abstract
Infant–parent interactions are bidirectional; therefore, it is important to understand how infants’ communicative behavior elicits variable responses from caregivers and, in turn, how infants’ behavior varies with caregivers’ responses; furthermore, how these moment-to-moment interactive behaviors relate to later language development. The current study addressed these concerns by observing 10- to 13-month-old infants’ interactions with their mothers and measuring their language outcomes when they were 15 months old. The main results were: (1) infants were more likely to combine vocalizations with pointing when mothers were not looking at the target of the point, and when mothers did not respond about the target of the point; (2) infants’ combination of vocalization and pointing behavior, especially those produced when mothers were not attending to the target object of the point, related to infants’ comprehension skills at 15 months as measured by the MacArthur Communicative Development Inventory (MCDI); (3) maternal follow-in responses were related to infants’ improvement in their comprehension and production scores on the MCDI. These results suggest that infants’ own prelinguistic communicative acts that are produced differentially as a function of maternal attention and responses, and the maternal responses that they elicit, contribute to infants’ subsequent language development.

Keywords
Communication, language development, maternal responses, MCDI, prelinguistic

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Introduction

Prior to the development of language, infants develop a rich prelinguistic communication system. The transition from prelinguistic to linguistic communication is suggested to be a continuous process (Reddy, 1999). Bates and colleagues have documented that the emergence of a series of gestures, such as giving, showing, pointing and ritualized reaches precede the appearance of first words (Bates, 1979; Bates, Camaioni, & Volterra, 1975). These gestures, pointing in particular, have been shown to relate to language development (Brooks & Meltzoff, 2008; Butterworth, 1998, 2003; Butterworth & Morissette, 1996; Capirci, Iverson, Pizzuto, & Volterra, 1996; Goldin-Meadow, 2007; LeBarton, 2010; Masur, 1982, 1983; Olson & Masur, 2011; Özçalışkan & Goldin-Meadow, 2005; Rowe, Özçalışkan, & Goldin-Meadow, 2008). Previous studies have focused mainly on how infants’ pointing gestures alone and pointing-plus-word combinations relate to language development independently; however, prior to the well-studied gesture-plus-word stage (Capirci et al., 1996; Goldin-Meadow, 2007; Iverson & Goldin-Meadow, 2005; Rowe et al., 2008; Rowe & Goldin-Meadow, 2009), infants combine prelinguistic vocalizations with gestures and eye contact during naturally observed social interactions (Bates et al., 1975; Bruner, 1975; D’Odorico, Salerni, Cassibba, & Jacob, 1999; Franco & Butterworth, 1996; Gros-Louis & Wu, 2012; Leroy, Mathiot, & Morgenstern, 2009; Messinger & Fogel, 1998; Miller & Lossia, 2013), yet we know little about how these combined behaviors relate to language development.

Infants’ combined communicative behaviors emerge around 9 months of age. Starting around 12 months old, infants flexibly produce combined communicative behaviors to engage a social partner. For example, Liszkowski, Albrecht, Carpenter, and Tomasello (2008) documented experimentally that when an adult partner ignored the presented stimuli, 12- and 18-month-old infants vocalized more and longer during and after pointing than when the adult partner responded to their pointing by making comments about the target object. Gros-Louis and Wu (2012) further found that 12-month-old infants were more likely to combine vocalizations with pointing gestures during free-play interactions when their parent was not looking at the target object compared to when their parent was already looking at it. These findings suggest that infants actively adjust their behaviors according to their social partner’s attention and responses.

Combining prelinguistic behaviors flexibly has been proposed to be an important achievement that marks more advanced communicative behavior. The basis of this communicative behavior coincides with developmental changes in social-cognitive skills (the ‘social-cognitive revolution’ – Tomasello, 1995). Researchers have suggested that flexibly producing variable combinations of prelinguistic behaviors may play a significant role in infants’ transition from prelinguistic communication to linguistic communication (Bates et al., 1975; Bruner, 1975; D’Odorico et al., 1999). Changing behaviors according to a partner’s responses may show infants’ awareness of the effects of their own behavior on others; furthermore, they may do it intentionally to have a preplanned effect on others (Bates, 1979; Bruner, 1981). Infants’ discovery that they can redirect others’ attention and influence others’ behavior may be essential to language acquisition (Bates, 1979).

In addition, infants’ flexible production of combined behaviors may elicit responses from caregivers about the focus of their attention in ongoing interactions, thereby
guiding the interaction (e.g., Vallotton, 2009; West & Rheingold, 1978) in a manner that supports language learning. Caregivers’ responses have been proposed to be a mediator of the relation between infants’ own communicative acts and their subsequent language outcomes (e.g., Masur, 1982, 1983; Masur, Flynn, & Eichorst, 2005; Olson & Masur, 2011, 2013). Infants’ combinations of pointing gestures and vocalizations are more likely to elicit caregivers’ contingent responses (e.g., Gros-Louis & Wu, 2012); in return, caregivers’ contingent responses facilitate more vocal + gestural productions in infants (e.g., Miller & Lossia, 2013). Furthermore, caregivers’ contingent responses are shown to be a significant contributor of infants’ language development (e.g., Dunham, 1995; Paavola, Kemppinen, Kumpulainen, Moilanen, & Ebeling, 2006; Paavola, Kunnari, & Moilanen, 2005; Paavola, Kunnari, Moilanen, & Lehtihalme, 2005; Tamis-LeMonda, Bornstein, & Baumwell, 2001). This suggests the interactional nature of infants’ and caregivers’ behaviors in language development (e.g., Smith, Adamson, & Bakeman, 1988): infants act, mothers interpret their acts as deictic, referential signals and provide a translation, and they both learn gradually to adjust their behaviors according to each other’s attention and responses, thus facilitating children’s linguistic communication.

In support of these arguments, Paavola and her colleagues (Paavola, Kunnari, & Moilanen, 2005; Paavola et al., 2006) showed that 10-month-old infants’ intentional communicative acts predict their comprehension and production scores measured by the MacArthur Communicative Development Inventory (MCDI) at 12 months. In their studies, an intentional communicative act was defined as ‘an event in which the infant directed a motoric and/or vocal act toward his/her mother as evidenced by eye gaze, body orientation or physical contact, and awaited a response, as evidenced by looking at the mother, hesitating or persisting in the communicative act’ (Paavola, Kunnari, & Moilanen, 2005, p. 729). These studies provided evidence that infants’ prelinguistic behaviors of eye gaze, gestures and vocalizations related to subsequent language development (see also Laakso, Poikkeus, Katajamäki, & Lyytinen, 1999). However, the definition of an intentional communicative act did not distinguish infants’ various combinations of behaviors relative to the partner’s attention and responses. Consequently, it is important to study how children’s capacity to variably produce prelinguistic communicative behaviors according to parents’ attentional states and responses relates to their subsequent language outcomes.

In the present study, we addressed two specific aims. First, we determined the extent to which infants vary their combinations of pointing gestures, vocalizations and gaze alternation behaviors (i.e., visual checking) relative to their mothers’ attentional states and responses, seeking to replicate and extend previous findings by Liszkowski et al. (2008) and Gros-Louis and Wu (2012) to a broader age range. In addition, the studies by Liszkowski et al. (2008) and Gros-Louis and Wu (2012) did not report whether infants changed their looking behavior according to parents’ attention and responses, which is an important indicator of communicative competency (Franco & Butterworth, 1996); therefore, the current study also aimed to fill this gap. We focused on 10- to 13-month-old infants’ communicative behaviors with their mothers, because this spans the period from when infants begin to display combinations of the above behaviors to when they do so more selectively (e.g., Gros-Louis & Wu, 2012), and it is also before they produce many words (Bates, 1979; Bates et al., 1975). Furthermore, this age period marks significant
changes in social-cognitive skills that support infant communicative behavior. For example, infants begin to understand others as intentional agents and acknowledge shared reference, as they perform visual checking to monitor joint engagement with a social partner (Bornstein, Vibbert, Tal, & O’Donnell, 1992; Franco & Butterworth, 1996; Thoermer & Sodian, 2001). On the basis of prior findings, we hypothesized that infants may be more likely to combine their vocalizations and visual checking behaviors with pointing gestures when the parent was not attentive, or when they did not respond sensitively.

Second, we aimed to test whether 10- to 13-month-old infants’ flexible production of different combinations of vocalizations, visual checking and pointing gestures related to their subsequent language development at 15 months. Previous studies have shown that infants’ pointing gestures alone, vocalizations alone, and maternal sensitive responses to these behaviors relate to infants’ vocabulary size (e.g., Brooks & Meltzoff, 2008; Butterworth & Morissette, 1996; Goldstein, Schwade, Briesch, & Syal, 2010; Harris, Yeeles, Chasin, & Oakley, 1995). Therefore, we hypothesized that infants’ combinations of pointing gestures, vocalizations, or visual checking would be related to their subsequent language outcomes. Nonetheless, because it is presently unknown what combinations of behavior relative to the partner’s attention or responses are associated with language measures, we did not have a priori hypotheses concerning differential correlations among different combinations of vocal/visual/gestural acts and language outcomes.

**Methods**

**Participants**

Ninety-five infants aged 10–13 months old ($M = 358.58$ days, range = 298–407 days; 34 females) participated. Ten infants were first-born. Participants were recruited from county birth records in a Midwestern US city and a database of infants whose parents had agreed to participate in studies of infant development. Participants were primarily Caucasian (one Asian and one east Indian), middle class, and all but one mother had completed at least some college ($M = 16.3$ years, range = 12–20 years). Average age of mothers was 33.5 years (range = 24–44).

Of the 95 participants, 51 infants ($M = 364.20$ days, $SD = 31.24$ days, range = 298–407 days; 29 females) displayed pointing during the 15-minute play session. Because we were interested in infants’ production of vocalizations and gaze alternation in the context of pointing, data analysis was based on the data of the 51 participants who pointed.

**Procedure**

Participants engaged in 15-minute natural free-play interactions with their mothers in a playroom that contained a variety of age-appropriate toys. Mothers were instructed to play as they would at home. Three wall-mounted video cameras (Sony EVI-D100) recorded interactions. Videofeed was routed through an audio-video mixer (Datavideo SE-800AVK) to allow for selection of the best camera angle or picture-in-picture
recording for observation of infants’ and mothers’ attentional focus. Audio recordings were made using a wireless microphone (Sennheiser ew112G2) sewn into overalls worn by the infant.

Mothers were requested to fill out the MacArthur Communicative Development Inventory: Words and Gestures (Fenson et al., 1993, 1994) twice, once when they visited the lab for the free-play interaction, and once when the infant was 15 months old. There was a number of missing MCDI scores due to participants not filling them out on time or not returning them. In total, 42 second sets of MCDI scores were used to assess how infant behavior and maternal responsiveness, observed when they first visited the lab, related to infants’ subsequent language measures at 15 months old; in addition, 26 complete sets of first and second MCDI scores were used to assess changes in language abilities from when infants first visited the lab to when they were 15 months old.

Coding

All coding was done using ELAN (EUDICO Linguistic Annotator – Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands; http://www.lat-mpi.eu/tools/elan/; Lausberg & Sloetjes, 2009), a free software program that allows for coding that is time locked with the video data. The coding focused on two aspects of the interaction: (1) infants’ pointing, vocalizing and visual checking; (2) mothers’ attentional states immediately preceding infants’ pointing and responses to infants’ points. Reliability was assessed by an independent coder who coded a random 25% of the sample.

Infants’ pointing and vocalization. Pointing was identified based on the behavioral appearance of the arm either fully or half extended toward a discernible object or location (Liszkowski, Carpenter, Henning, Striano, & Tomasello, 2004). Pointing was distinguished from a clear attempt to only grab or touch something and from loose arm movements or undirected excitement. Coders agreed on 91% of cases of infants’ pointing, and the number of points identified by coders was highly correlated, interrater reliability = .90.

Vocalizations included any sound that infants produced except fussing or vegetative sounds (e.g., hiccups, coughs). Vocalizations were coded as follows: vocalizing or no vocalizing during pointing and within 2 s after mother’s response to the pointing. Interrater reliability was .94 for vocalizations during pointing and after mother’s response.

Visual checking was coded as infant’s first look to the mother during pointing and within 2 s after mother’s response to the pointing, as described above for vocal coding (Franco & Butterworth, 1996). Interrater reliability for visual checking was .87 and .89 for during and after pointing, respectively.

Mothers’ attentional states and responses. Maternal attentional focus before infants’ pointing was coded in the following two categories: (1) target = the mother was already attending to the object that was pointed to by the infant subsequently; (2) nontarget = the mother was not attending to the target object, i.e., the mother was either looking at the infant or another object when the infant pointed. Maternal responses were defined as any
behavior that occurred during pointing, or within 2 s of the end of infants’ pointing if mothers did not respond while infants were pointing (Gros-Louis, West, Goldstein, & King, 2006). Responses were coded based on how they related to the target of infants’ pointing (i.e., the object that infants were pointing to). Sensitive responses included comments or actions on the object that the infant was pointing to (i.e., ‘follow-in responses,’ see Tomasello & Farrar, 1986). Redirective responses, on the other hand, were comments or actions on objects that were not the target of infants’ pointing (‘directive,’ see Baldwin et al., 1996). Asking questions (AQ) was coded if the mother asked the infant a question in response to the pointing (e.g., What do you want? Is that a tiger?). The last category, No response, referred to the situation when mothers just sat watching infants play but did not say or do anything. Average interrater reliability was .77 and .86 for maternal attentional states and responses, respectively.

Results
The results are reported in four sections. First, we report descriptive statistics of infants’ and mothers’ behaviors during mother–infant interactions, and children’s language skills as measured by the MCDI. Second, we report infant vocal production and visual checking behavior during pointing as a function of maternal attentional states. We also report infant vocalizations and visual checking after pointing relative to maternal responses to their pointing. This part of the data analysis was conducted in the open-source program R, using the generalized linear mixed model (Baayen, Davidson, & Bates, 2008). We used this model to analyze data rather than variance analysis (e.g., F test) or means comparison (e.g., t test) because this model incorporates both fixed (independent variables) and random effects (individual differences). Third, we examine the relations of both infants’ and mothers’ interactive behaviors to infants’ linguistic skills. Lastly, we investigate the association between infants’ and mothers’ interactive behaviors and infants’ linguistic skills. The last part of the data analysis was conducted in SPSS 19, using Pearson product-moment correlations.

Descriptive statistics
Table 1 presents descriptive statistics for mother–infant interaction variables and infants’ MCDI scores. Independent-samples t tests with mother–infant interaction variables and infants’ MCDI scores as the dependent variables and gender as the independent variable showed that there was no significant gender effect on infant and maternal interactive behaviors, t(49) ranged from 0.03 to 1.57, ps > .05; however, females had significantly higher comprehension (M = 171.35, SD = 93.67) and gesture scores (M = 40.61, SD = 9.70) on the MCDI measured at 15 months old than males did (Mcomprehension = 117.00, SDcomprehension = 61.33; Mgesture = 32.95, SDgesture = 10.29), t(40) = 2.17, 2.48, p = .04, .02 respectively, but females and males did not differ in their vocabulary production scores, t(40) = 1.41, p = .17. In terms of language improvement measured between the first and second sets of MCDI, females (M = 17.53, SD = 7.61) made significantly greater improvements on gesture production than males did (M = 10.64, SD = 7.43), t(24) = 2.30,
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p = .03, but not on production or comprehension, \( t(24) = 1.64, 0.61, p = .11, .55 \) respectively.

Next, we examined infants’ combined behaviors and mothers’ responses. A 2 (time: during pointing vs. after pointing) × 2 (behavior: vocalizing vs. visual checking) repeated measure analysis with the proportion of infants’ behavior as the dependent variable showed that infants overall produced significantly more vocalizing than visual checking, \( F(1, 50) = 28.88, p < .001, \) partial \( \eta^2 = .37 \); they vocalized more during pointing than after pointing, \( F(1, 50) = 27.87, p < .001, \) partial \( \eta^2 = .36 \), but there were no differences between visual checking during and after pointing, \( F(1, 50) = 1.52, p = .22, \) partial \( \eta^2 = .03 \). To examine maternal responses, we conducted a repeated measure analysis with the frequency of four kinds of maternal responses as the dependent variable and the frequency of total responses as the covariate. Results showed that there were marginally significant differences in maternal responses, \( F(3, 47) = 2.33, p = .09 \); mothers were most likely to provide sensitive responses, followed by no responding, asking questions and redirective responding. Adjusted Bonferroni pairwise comparisons showed that each of the six pairwise comparisons was significant except for the difference between asking questions and redirective responding (\( p = 1.00 \)), and the difference between asking questions and no response (\( p = .26 \)).

### Table 1. Means, standard deviations and ranges for infant and maternal interactive behaviors and infants’ MCDI scores.

<table>
<thead>
<tr>
<th>Variable</th>
<th>M</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Infant interactive behavior</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of points</td>
<td>5.71</td>
<td>6.14</td>
<td>1–30</td>
</tr>
<tr>
<td>Proportion of vocalization during pointing</td>
<td>.56</td>
<td>.37</td>
<td>0–1</td>
</tr>
<tr>
<td>Proportion of vocalization after pointing</td>
<td>.30</td>
<td>.29</td>
<td>0–1</td>
</tr>
<tr>
<td>Proportion of visual checking during pointing</td>
<td>.26</td>
<td>.28</td>
<td>0–1</td>
</tr>
<tr>
<td>Proportion of visual checking after pointing</td>
<td>.24</td>
<td>.28</td>
<td>0–1</td>
</tr>
<tr>
<td><strong>Maternal interactive behavior</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of non-target attention before infants pointed</td>
<td>3.84</td>
<td>4.66</td>
<td>0–20</td>
</tr>
<tr>
<td>Number of target attention before infants pointed</td>
<td>1.86</td>
<td>2.32</td>
<td>0–10</td>
</tr>
<tr>
<td>Proportion of redirective response after pointing</td>
<td>.07</td>
<td>.15</td>
<td>0–1</td>
</tr>
<tr>
<td>Proportion of ‘no response’ after pointing</td>
<td>.18</td>
<td>.28</td>
<td>0–1</td>
</tr>
<tr>
<td>Proportion of asking questions after pointing</td>
<td>.11</td>
<td>.18</td>
<td>0–1</td>
</tr>
<tr>
<td>Proportion of sensitive response after pointing</td>
<td>.64</td>
<td>.38</td>
<td>0–1</td>
</tr>
<tr>
<td><strong>Infants’ MCDI scores</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production at 15 months(^a)</td>
<td>31.45</td>
<td>33.72</td>
<td>0–153</td>
</tr>
<tr>
<td>Comprehension at 15 months(^a)</td>
<td>146.76</td>
<td>84.32</td>
<td>21–360</td>
</tr>
<tr>
<td>Gesture at 15 months(^a)</td>
<td>37.14</td>
<td>10.58</td>
<td>8–61</td>
</tr>
<tr>
<td>Increased production(^b)</td>
<td>27.92</td>
<td>31.75</td>
<td>1–144</td>
</tr>
<tr>
<td>Increased comprehension(^b)</td>
<td>91.35</td>
<td>64.50</td>
<td>8–206</td>
</tr>
<tr>
<td>Increased gesture(^b)</td>
<td>14.62</td>
<td>8.16</td>
<td>2–28</td>
</tr>
</tbody>
</table>

\(^a\) Based on 42 infants’ data; \(^b\) based on 26 infants’ data.
We used the generalized linear mixed model (see Baayen et al., 2008) to analyze how infants change their vocal production and visual checking behavior in relation to maternal attentional states and responses. As shown in Table 1, across the participants, the number of maternal ‘nontarget’ attention states ranged from 0 to 20, and the

**Figure 1.** (a) The proportion of infants’ vocalizing and visual checking during pointing as a function of maternal attentional states (nontarget vs. target); (b) the proportion of infants’ vocalizing and visual checking in response to different types of maternal responses.

**Infants’ vocalizations and visual checking relative to maternal attention and responses**

We used the generalized linear mixed model (see Baayen et al., 2008) to analyze how infants change their vocal production and visual checking behavior in relation to maternal attentional states and responses. As shown in Table 1, across the participants, the number of maternal ‘nontarget’ attention states ranged from 0 to 20, and the
number of maternal ‘target’ attention states ranged from 0 to 10. That is, some mothers did not look at the target object before infants’ pointing at all during the 30-minute interaction, while others were always looking at the target object when the infant pointed. Consequently, directly comparing means or variances of infants’ proportion of vocalizations/visual checking relative to maternal attentional states is not powerful. The average adjustment was thus required to account for individual differences in maternal attentional states. Therefore, we used the proportion of infants’ vocalization when they pointed as the dependent variable and maternal attentional states (nontarget vs. target), infants’ age and gender as independent variables; the individual differences among participants were entered as a random effect. The model found no significant effect of age or gender, but infants vocalized significantly more when their mother was not looking at the target than when their mother was looking at the target, $z = 3.20, p = .001$ (Figure 1a).

Similarly, for each participant, the four different kinds of maternal responses (sensitive, redirective, ask questions, no response) varied, as shown in Table 1. Therefore, we used the proportion of infants’ vocalization after maternal response as the dependent variable and maternal response type, infants’ age and gender as independent variables; the individual differences among participants were entered as a random effect. We found no significant effect of age or gender on infants’ vocalization after maternal response, but maternal response type was a significant predictor of infants’ vocalization after maternal response. Infants vocalized significantly less when their mother responded sensitively than when their mother did not respond sensitively, $z = −2.82, p = .005$ (Figure 1b).

Using the same method, we also examined infants’ visual checking during pointing and after maternal response. When infants’ visual checking during pointing was the dependent variable, the independent variables were maternal attentional states, infants’ age and infants’ gender, whereas maternal responses, infants’ age and infants’ gender were independent variables when infants’ visual checking after maternal response was entered as the dependent variable. The individual differences among participants were entered as a random effect. No significant effects of age or gender were found. Infants’ visual checking during pointing did not vary with maternal attentional states, $z = .03, p = .49$ (Figure 1a); however, infants’ visual checking after maternal response varied relative to maternal response type, $z = 1.69, p < .05$. Infants produced significantly more visual checking when mothers provided redirective responses than any other responses, $ps < .05$ (Figure 1b).

**Correlations between infants’ and maternal communicative behaviors and language development**

Pearson’s correlational analysis found that infants’ frequency of pointing and proportion of visual checking after pointing during their first visit (at 10, 12, or 13 months) significantly correlated to their production score at 15 months, $r(42) = .33, .31, p = .034, .047$, respectively; the proportion of vocalizations during pointing correlated to their comprehension score at 15 months, $r(42) = .31, p = .047$ (Table 2).

The relationship between infants’ vocal production relative to maternal attentional states, maternal responses and MCDI scores were analyzed (Table 3). Pearson’s
Table 2. The relationship between infants’ interactive behavior and their MCDI scores at 15 months.

<table>
<thead>
<tr>
<th></th>
<th>Point Vocalize during point</th>
<th>Vocalize after point</th>
<th>Visual check during point</th>
<th>Visual check after point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>.33*</td>
<td>.11</td>
<td>.04</td>
<td>.12</td>
</tr>
<tr>
<td>Comprehension</td>
<td>.12</td>
<td>.31*</td>
<td>−.11</td>
<td>.22</td>
</tr>
<tr>
<td>Gesture</td>
<td>.13</td>
<td>.23</td>
<td>−.18</td>
<td>.11</td>
</tr>
</tbody>
</table>

Correlational analysis found that infants’ vocal production during pointing when mothers were not attending to the target object positively correlated to infants’ comprehension scores measured at 15 months; however, infant vocal production after their mothers responded sensitively to their pointing negatively correlated to their comprehension and production scores measured at 15 months.

Before examining the relation between infants’ interactive behavior and their improvement in their language ability from their first visit to when they were 15 months old, we investigated if infants’ language improvement was related to their age at their first visit (range = 298–407 days), because there potentially might be a larger increase for younger infants than for older infants. We found that infants’ increased production, increased comprehension and increased gesture scores were not significantly correlated to age at first visit, \( r(26) = −.38, −.05, −.37, \) \( p = .06, .82, .06 \) respectively. Because one may argue that \( p = .06 \) is marginally significant, to be more conservative, we controlled for age when analyzing the correlations between infants’ interactive behavior and change in language scores. With age controlled, Pearson’s partial correlation analysis found that infants’ vocalizations after maternal sensitive responses negatively correlated to their increased comprehension scores from their first visit to 15 months of age; meanwhile, infants’ visual checking after maternal redirective responses positively correlated to their increased comprehension scores. In addition, infants’ vocal production after mothers asked questions about the pointing positively correlated to infants’ increased production scores from their first visit to 15 months of age (Table 4).

Next, we analyzed the relationship between maternal responses and infants’ vocabulary development as measured by the MCDI. After controlling for age, no significant correlations were found between different types of maternal responses (the frequency and the proportion of asking questions, sensitive responses, redirective responses and no response) and production, comprehension, or gesture scores on the MCDI at 15 months old; however, maternal responses were related to infants’ language improvement after controlling for age. Specifically, the frequency of maternal redirective responses to infants’ pointing was negatively associated to infants’ improvement in their gesture scores, \( r(23) = −.42, p = .04 \); and the frequency of not responding to infants’ pointing was negatively correlated to infants’ improvement in their comprehension scores, \( r(23) = −.40, p = .05 \). In addition, the frequency of maternal sensitive responses was marginally correlated to infants’ improvement in their comprehension scores, \( r(23) = .35, p = .08 \).
Table 3. The relations of MCDI scores at 15 months to infants’ vocalizations and visual checking during pointing relative to different maternal attentional states (target, nontarget) and after maternal responses.

<table>
<thead>
<tr>
<th>Maternal attentional states</th>
<th>Maternal responses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nontarget</td>
</tr>
<tr>
<td></td>
<td>Voc</td>
</tr>
<tr>
<td>Production</td>
<td>.09</td>
</tr>
<tr>
<td>Comprehension</td>
<td>.42*</td>
</tr>
<tr>
<td>Gesture</td>
<td>.23</td>
</tr>
</tbody>
</table>

Voc: vocalization; VC: visual checking.
Table 4. The partial relations, after controlling for age, of infants’ MCDI scores to infants’ vocalizations and visual checking during pointing relative to different maternal attentional states (target, nontarget) and after maternal responses.

<table>
<thead>
<tr>
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<tr>
<td></td>
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<tr>
<td>Increase production</td>
<td>.09</td>
</tr>
<tr>
<td>Increase comprehension</td>
<td>.30</td>
</tr>
<tr>
<td>Increase gesture</td>
<td>.24</td>
</tr>
</tbody>
</table>

Voc: vocalization; VC: visual checking.
Discussion

There were three main findings in this study: (1) Infants varied their behaviors according to their mother’s attentional states and responses about the focus of infants’ pointing; (2) infants’ flexible use of communicative behaviors related to subsequent language skills; (3) maternal responses to infants’ pointing were associated with improvements in language skills.

First, the current findings provide suggestive evidence that infants intentionally modify their behavior to engage their mothers and elicit responses about the target of their pointing. Three criteria are often used in making distinctions about whether or not a behavior is intentionally communicative: (a) the behavior varies in accordance with the attentional states of the audience; (b) the behavior is accompanied by gaze alternation between an observer and an object or event of interest; and (c) the behavior is goal directed and continues until the desired outcome is reached (Bates et al., 1975; Leavens & Hopkins, 1999; Liszkowski et al., 2008). Infants vocalized more when mothers were not attending to the target object, which supports the first part of the definition of intentional communication. Additionally, infants alternated their gaze between their mother and the target of their pointing, particularly when mothers did not respond about the target object, which supports the second part of the definition. Moreover, when mothers did not respond to infants’ pointing, infants were more likely to vocalize and look back toward mothers, suggesting that they were trying to relay the message (see also Golinkoff, 1986). These findings add to a growing number of experimental studies that have documented goal-directed behavior that continues until a desired outcome is reached (e.g., Liszkowski et al., 2004, 2008; Tomasello, Carpenter, & Liszkowski, 2007). Together, these studies provide support for the suggestion that infants’ communicative behavior, specifically the integration of alternating eye gaze, vocalizations and gestures, is indicative of infants’ intention to communicate (Bates, 1979; Bates et al., 1975; Bruner, 1975; Wetherby, Cain, Yonclas, & Walker, 1988; see also Harding & Golinkoff, 1979).

Previous researchers have suggested that these pre-intentional communicative behaviors may help infants transit from the prelinguistic communication stage to the linguistic stage (e.g., Bates, 1979; Paavola, Kunnari, & Moilanen, 2005). Intervention studies on prelinguistic children with developmental delays have shown that increasing infants’ intentional communication led to an increase in maternal responses that positively influence language development (Yoder & Warren, 2001). In support of this hypothesis, we found that that infants’ flexible prelinguistic communication supports their language learning. Specifically, infants’ combination of vocalizing and pointing when mothers were not attending to the target of infants’ pointing positively predicted infants’ comprehension scores; whereas, infants’ vocalizations after mothers responded sensitively to infants’ pointing were negatively associated with comprehension. Moreover, infants were more likely to look back to their mothers when mothers provided directive responses, which were unrelated to the target of infants’ pointing. This visual checking behavior after maternal directive responses positively associated with their verbal production a few months later. Thus, infants’ initial comprehension and nonverbal communicative behavior play a role in further development through their effect on infants’ communication with their mothers as interactions unfold moment-to-moment. Previous
studies have shown that gesture–word combinations precede two-word combinations (Capirci et al., 1996), and, furthermore, the combination of pointing and one word predicts the onset of two-word combinations (Goldin-Meadow, 2007; Iverson, Capirci, Volterra, & Goldin-Meadow, 2008; Iverson & Goldin-Meadow, 2005). Our results thus supplement these findings by showing that, at an earlier age before infants produce gesture–word combinations, gesture–vocal combinations relate to infants’ linguistic skills measured at 15 months of age.

Flexible production of communicative behaviors, i.e., variable production with regard for mothers’ attentional states and responses, can facilitate language development in two related ways: (1) infants establish joint attention episodes and joint reference to objects; (2) infants’ behaviors help parents to interpret infants’ communication. In our study, infants flexibly produced combined behaviors, which showed their efforts in attracting mothers’ attention and establishing joint engagement (Gros-Louis & Wu, 2012; Liszkowski, 2008; Liszkowski et al., 2004). By actively monitoring and modifying their behaviors, infants thus play a role in guiding the interactions (see also West & Rheingold, 1978), such as establishing or maintaining joint attention episodes, which increase between 12 and 18 months and are critical for language learning (Bakeman & Adamson, 1984; Baldwin, 1991, 1993, 1995; Carpenter, Nagell, & Tomasello, 1998; Tomasello & Farrar, 1986). Furthermore, gestures such as pointing establish joint reference, which is particularly important for language development (e.g., Bruner, 1975; Tomasello et al., 2007). In addition, visual checking in slightly older toddlers has been shown to help establish joint reference to objects, thereby aiding in learning labels (Baldwin, 1995). Thus, infants can contribute to their own language learning through their own communicative abilities by guiding the interactions and creating situations of shared reference (Smith et al., 1988).

Meanwhile, infants’ moment-to-moment interactions elicit maternal responses that facilitate their language learning. In addition to establishing shared reference, infants’ pointing influences parents’ responses because pointing, defined as a ‘deictic gesture,’ is used to refer to external objects or events. Furthermore, when infants’ gesture and intonation contour are coordinated, social partners can more easily interpret the intended meaning (Balog & Brentari, 2008). Similarly, gaze alternation with gestures and vocalizations helps mothers interpret the meaning of their children’s preverbal communication (Golinkoff, 1986). Thus, when infants point and vocalize to an external event or object in the environment, the social partner interprets infants’ behavior as referential and communicative, and responds accordingly, which facilitates the transition to linguistic communication (Carpendale & Carpendale, 2010; Carpendale & Lewis, 2004; Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007; Jones & Zimmerman, 2003).

A third finding of the current study was that how mothers responded to infants’ pointing related to infants’ developing language skills. Maternal redirective responses negatively related to infants’ improvement in their gesture scores. In addition, there was a negative relation between mothers’ lack of responding and children’s improvement in comprehension, whereas sensitive responses were positively related to children’s improvement in comprehension. This finding adds more evidence to support prior studies that have shown that maternal responses to infants’ vocal and nonvocal behavior play an important role in children’s advances in language (e.g., Dunham, 1995; Paavola et al.,
In addition, similar to prior studies, we found that redirecting the infant’s focus of attention, as opposed to following it, hinders language acquisition (Akhtar, Dunham, & Dunham, 1991; Della Corte, Benedict, & Klein, 1983; Tomasello & Farrar, 1986). Interestingly, we did not find significant relationships between maternal responses and infants’ overall vocabulary production, comprehension or gesture measured at 15 months. This suggests that infants’ initial developmental level should be taken into account when considering the role of maternal responses in children’s language development, as previous studies also showed that parent responses vary depending on the developmental level of infants’ communicative behaviors (Gros-Louis et al., 2006; Masur, 1983).

Because of the relatively small sample size and the homogeneity of participants from well-educated middle-class families, generalization of the results presented in this article should be made with caution. Nonetheless, data from naturalistic observations are valuable because they provide important information regarding typical mother–infant interaction; however, one limitation of observational studies is that it makes systematic comparisons difficult. For example, mothers provided significantly more sensitive responses than redirective responses during natural observation. Although this falls in the range of what is reported in the literature (e.g., Dewey & Gros-Louis, under review; Paavola, Kunnari, Moilanen, & Lehtihalmes, 2005), this makes comparisons of infants’ behavior after maternal responses relatively hard. To further investigate this issue, researchers could experimentally manipulate maternal responses to systematically explore the effect of maternal responses on prelinguistic communicative behavior during mother–infant interactions (e.g. Miller & Gros-Louis, 2013; Miller & Lossia, 2013).

The current study demonstrates that infants’ flexible production of prelinguistic communicative behaviors, and maternal responses to those behaviors, relate to the development of infants’ subsequent language skills. Infants’ early combination of pointing and prelinguistic vocalizations that vary with mothers’ attention and responses are associated with subsequent verbal comprehension, and the combination of pointing and visual checking is associated with verbal production. Furthermore, results suggest that infants’ efforts in establishing joint reference, e.g., vocalizing during pointing when their mother was not attentive or vocalizing and/or visual checking after pointing when their mother did not respond, support the development of language. In addition, consistent with prior findings, maternal sensitive responses relate to children’s improvement in language skills whereas redirective responses negatively affect children’s language development. Future studies should assess the relationship of these variables to language development over time, as mothers are sensitive to changing abilities of their infants (e.g., Bornstein et al., 1992). As infants develop the ability to actively establish joint attention or initiate interactions (Baldwin et al., 1996), they may also develop the ability to actively solicit information that they do not have words for yet; the language input they receive that is specific to what they are attempting to communicate about at a given moment, which will vary across infants, may be more likely to enter their vocabulary (Goldin-Meadow, 2007; Southgate, van Maanen, & Csibra, 2007). Therefore, a differential relationship among infants’ own behaviors, maternal responses and language development may exist at different points in language development.
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