Supporting early vocabulary development: What sort of responsiveness matters?

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***Abstract* - Maternal responsiveness has been positively related with a range of socio-emotional and cognitive outcomes including language. A substantial body of research has explored different aspects of verbal responsiveness. However, perhaps because of the many ways in which it can be operationalised, there is currently a lack of consensus around what type of responsiveness is most helpful for later language development. The present study sought to address this problem by considering both the *semantic* and *temporal* dimensions of responsiveness on a single cohort while controlling for level of parental education and the overall amount of communication on the part of both the caregiver and the infant. We found that only utterances that were both semantically appropriate and temporally linked to an infant vocalization were related to infant expressive vocabulary at 18 months.**

Index terms- Maternal responsiveness; vocabulary development; dyadic interaction

I. INTRODUCTION

Maternal Responsiveness or "prompt, contingent and appropriate reactions" to infant behaviors (Bornstein, Tamis-LeMonda, Hahn, & Haynes, 2008) is a multi-dimensional construct that has been found to be positively related to the infant's later socio-emotional and cognitive development (Ainsworth & Bell, 1974; Bornstein et al., 1992; Landry, Smith, Swank, Assel, & Vellet, 2001; Tamis-LeMonda & Bornstein, 2002). In particular, verbal responsiveness has been found to be positively correlated with a variety of language outcomes including lexical, syntactic and literacy skills (Masur, Flynn, & Eichorst, 2005; Rollins, 2003; Tamis-LeMonda, Bornstein, & Baumwell, 2001; Taylor, Anthony, Aghara, Smith, & Landry, 2008). Verbal responsiveness has been proposed to facilitate infants' language learning by encouraging and reinforcing their communicative behaviors within an interactional framework (Hoff & Naigles, 2002; Tomasello & Todd, 1983; Tomasello & Farrar, 1986).

However, despite these theoretical assumptions and a considerable body of research, experimental studies have not produced a clear consensus regarding which aspect of verbal responsiveness is most helpful for language development. Inconsistent findings may be due to the many ways in which responsiveness has been operationalised or to a range of other factors that differ across studies. These include the choice of environmental controls (e.g., infant and parent volubility; socio-economic status), the developmental age or level of the child (when both predictor and outcome measures are taken) and the choice of outcome measure (e.g., reported versus observed vocabulary levels; see Masur et al., 2005 for a full discussion). Therefore, not only do we not have a clear understanding of which types of responsiveness promote development, but more fundamentally we do not have a clear understanding of the basic mechanisms that underwrite the association between responsiveness and learning (Bornstein et al., 2008). Understanding these mechanisms is particularly important since clinical and educational interventions are often based on the assumption that encouraging some form of responsiveness on the part of parents should be effective in promoting child language (e.g., Landry et al., 2001).

The current study sought to address this issue by considering different types of responsiveness and exploring how they relate to each other and to standard measures of infant directed speech (IDS), the ultimate aim being to understand which measures of responsiveness, if any, best predict vocabulary development.

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Operationalizing Responsiveness

Historically, researchers interested in responsiveness focused on the relationship between language development and maternal behaviors that seek to engage with versus direct the child. Directive talk was found to be negatively associated with language outcomes (Nelson, 1985). Subsequent research has produced a more nuanced picture of maternal directiveness and one that does not necessarily suggest a negative impact on development (Akhtar, Dunham, & Dunham, 1991; Masur et al., 2005; Pine, 1992). Building on these observations, several studies have since continued to explore different dimensions of responsiveness, with a focus on considering the pragmatic functions of caregivers' speech with their infants from 9 months (Tamis-LeMonda et al., 2001; Tamis-Lemonda, Bornstein, Kahana-Kalman, Baumwell, & Cyphers, 1998) through the first year (Akhtar et al., 1991) and beyond (Hoff & Naigles, 2002).

A second (though overlapping) approach to the study of responsiveness has focused on the tendency of parents to talk about what is in their child's current focus of attention (sometimes referred to as *following in;* Carpenter, Nagell, Tomasello, Butterworth, & Moore, 1998). It is proposed that this type of *semantically contingent talk* facilitates vocabulary growth by making it easier for the infant to begin matching the phonological form of a word with its function (Akhtar & Tomasello, 2000). Indeed, correlational studies in the US have shown that mothers who engage in more semantically contingent talk have children who go on to have larger vocabularies (Carpenter et al., 1998; Hoff, 2003; Pine, 1992; Rollins, 2003). Moreover, Hoff (2003) has argued that this measure of responsiveness is particularly important in explaining the large individual differences in language outcomes that are associated with differences in socio-economic status.

A third way of measuring responsiveness is to consider whether a caregiver's utterance is *temporally contingent* on some act on the part of the child. Typically, temporal contingency is measured by calculating the proportion of infant communicative acts that are responded to within a given time frame. However, temporally contingent utterances can also be calculated as a proportion of total infant directed speech. Either way, there is a lack of consensus as to the optimal temporal window for an appropriate response, with studies either not specifying a specific timeframe or choosing a 2-5 second interval (Bornstein et al., 2008; Masur et al., 2005; Pine, 1992). This type of responsiveness is relatively under-explored, which is perhaps surprising, given that it can be measured even in the earliest dyadic interactions and gives the infant a foothold in the pragmatics of turn-taking (Casillas, forthcoming).

It is quite possible that different types of responsiveness have subtly different effects on language learning and are more or less important at different stages of development. When infants are on the cusp of triadic communication (where caregiver and child comment on the external world - around 9 to 12 months), utterances that are both semantically and temporally contingent might be particularly helpful as they essentially result in proto-conversations, where the infant vocalizes and the parent 'translates' this into conventional language (Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979). This could arguably provide the infant with linguistic forms at the point when they are likely to be most receptive to them. Moreover, talk that is semantically contingent on a child's focus of attention and temporally contingent on their vocalizations could scaffold the transition from dyadic to triadic interactions, shaping infant's vocalizations into something that can be produced intentionally as a means of regulating the other's attention. To test whether this is the case, however, it is necessary to control for other aspects of Infant Directed Speech (IDS) that have consistently been found to be associated with child language outcomes.

Controlling for other Measures: IDS, SES and Infant Communicative Ability

It is generally agreed that the responsive quality of caregivers' speech is only one of many aspects of infant directed speech that predict language learning. For example, there is good evidence, derived largely from North American observational studies, that parents who simply talk more to their infants have children who acquire language quicker (Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991) and have larger vocabularies (Hart & Risley, 1995). Moreover, there are widely replicated correlational findings which suggest that dense, syntactically complex and lexically diverse infant directed speech is related to higher vocabulary levels in the first two years of life and beyond (Akhtar et al., 1991; Bornstein, Haynes, & Painter, 1998; Hart & Risley, 1995; Hoff & Naigles, 2002; Hoff, 2003; Huttenlocher et al., 1991; Pan, Rowe, Singer, & Snow, 2005). All of these differences in IDS are associated with socio economic status or parental education (Hart & Risley, 1995; Hoff, 2003; Hoff-Ginsberg, 1991). When testing the predictive power of responsive talk, studies vary as to whether they control for other aspects of child directed speech and/or a measure of SES, which presumably also contribute to the heterogeneity of findings.

Since language learning is something that happens in dyadic and polyadic interactions, we must also factor in the communicative ability and inclination of the child (Flynn & Masur, 2007). Infants have a developing range of socio-cognitive skills at their disposal which allow them to engage in interactions (both dyadic and triadic). In the pre-linguistic phase, gesture, particularly pointing (appearing around 11 months) has arguably received the lion's share of attention in the literature (Colonnesi, Stams, Koster, & Noom, 2010). However, there is a growing body of experimental work suggesting that early vocalizations (present from around 5 months) are also important communicative signals (Goldstein, Schwade, Briesch, & Syal, 2010; Goldstein, Schwade, & Bornstein, 2009).

Considering these early communicative behaviors is obviously necessary when calculating temporal responsiveness (since the child must first produce some communicative act for the caregiver to respond to). But it is plausible that the child's communicative ability also affects other types of responsiveness since the way a caregiver communicates is often tightly yoked to their perception of their child's developmental level (Dominey & Dodane, 2004; Fernald, 1989). It is well established that there are considerable individual differences in the amounts that infants vocalize (Stoel-Gammon, 1998; Vihman, 1996) and gesture (Colonnesi et al., 2010) and these have been found to be predictive of later language success. However, there is no agreed upon way of controlling for the child's developmental level when testing for associations between responsiveness and language learning. Options include testing children with a similar language age rather than chronological age (Pine, 1992) or statistically controlling for the child's communicative ability (Tamis-LeMonda et al., 2001), which is the approach we take here.

The Current Study

The overriding goal of this study was to explore the 'internal structure' of the responsiveness construct (Bornstein et al., 2008), and to test which types of responsiveness best predict vocabulary learning. To do this we analyzed video-recordings of forty-six British mothers and their infants aged 9.5 months. We transcribed both infant and caregiver vocalizations, coding the latter for common control measures of IDS quality and quantity (token and type frequency, lexical diversity, mean length of utterance and speech density). Each caregiver utterance was coded for its *semantic contingency* on the child's focus of attention. Two proportional measures of *temporal contingency* were derived. The first was the proportion of maternal utterances that were produced within two seconds of an infant vocalization. The second was the proportion of infant vocalizations that were responded to within two seconds. Finally, a measure of *temporal and semantic contingency* was derived by counting the proportion of maternal utterances that were both semantically contingent and produced within two seconds of an infant vocalization. We tested which of these measures of responsiveness best predicted child vocabulary at 18 months while controlling for maternal education and the quantity of parent speech and infant vocalizations.

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II. METHOD

Participants

The dataset coded here was collected in the North of England as part of a nine month longitudinal study of phonological development (DePaolis & Keren-Portnoy, under review). Fifty nine parent-infant dyads were recruited via advertisements in local press and playgroups. From this group, 48 parents gave full informed consent for their infants' data to be used in further research. Of this subset, one infant was excluded from the sample due to developmental condition and another because play sessions were not recorded with a primary caregiver. The remaining 46 infants were all full term and had no known hearing or developmental disorders. Twenty five were girls; 21 were first born; and all came from monolingual English speaking families. The sample was predominantly white and middle class. Fifty-eight percent of parents and 70% of mothers were university educated.

Procedure

Infants were video and audio recorded in their homes at least once per month between the ages of 9 and 18 months engaging in 30 minutes of naturalistic play with a caregiver. Parents were told that their infant's babble was the focus of the video recordings. They were encouraged to play normally with their infant and, aside from a request to refrain from playing with battery operated musical toys (which make transcription of infant speech sounds difficult), they were given no further guidance in structuring the interaction. An observer was present throughout the play session to operate the recording equipment. Observers did not initiate interaction with the caregiver or infant but followed the participants' lead and only contributed to the interaction on the mother's or infant's initiation.

For the purposes of this study, we analyzed 10 minutes of dyadic interaction recorded when the infant was 9.5 months (Mean age = 290 days; Range = 20 days). Across all recordings, the infant was not visible on camera for an average of 16.7 seconds (Range: 0-92 seconds). In all cases the infant's mother was the interactive partner. The 9.5 month video recording took place on the second

(65%) or third (35%) home visit. This allowed both the parent and infant to become accustomed to the observational procedure. The second home visit was chosen preferentially except in cases where: the person interacting with the child was not the primary caregiver; siblings or other infants were present; more than one parent was interacting with the infant; or there were technical difficulties with video or audio.

Across all dyads, minutes 5-15 of the 30-minute recording were analyzed. This simultaneously allowed parent and infant to "settle into" the recording session whilst minimizing fatigue effects. These 10 minute clips were continuous and uninterrupted in all but one dyad, where recording was stopped and restarted to facilitate infant caretaking.

Infant Vocalisations

As part of the original study, all infant vocalisations were phonetically transcribed by a team of three trained research assistants (including the first author) using EUDICO Linguistic Annotator software (ELAN; Sloetjes & Wittenburg, 2008). This transcription was checked and supplemented as part of the current study to include all non-vegetative infant vocalisations. The total number of non-vegetative infant vocalisations across the 10 minutes of interaction was summed to produce an *infant vocalisation count*.

Infant Directed Speech

In addition, all adult speech (both primary caregiver & observer), including onomatopoeic and evaluative sounds, was transcribed orthographically using ELAN software (Sloetjes & Wittenburg, 2008) following CHILDES's CHAT conventions (MacWhinney, 2000). Intonation and pause breaks were used to delimit utterances.

For all speech directed towards the infant by the primary caregiver, CLAN (MacWhinney, 2000) was used to calculate *mean length of utterance* (MLU – a measure of the sentence complexity of adult speech in morphemes); *number of word types*; *number of word tokens* and *vocabulary diversity* (*VOCD*: a measure of parent's lexical diversity independent of sample size; Malvern, Richards, Chipere, & Durán, 2004). The total number of utterances divided by the time (in milliseconds) taken to utter them was calculated as a measure of *Speech Density* (Akhtar et al., 1991).

Responsiveness

Maternal Responsiveness was coded in three waves:

Semantic contingency: Each maternal utterance was coded for its semantic contingency relative to the infant's focus of attention in the 2- second window preceding the utterance onset. A 2-second time window was chosen for all three measures of contingency (Goldstein & Schwade, 2008; Masur et al., 2005; Pine, 1992). This time span lies at the conservative end of the range reported in the literature on responsiveness (2-7 seconds; Jaffe et al., 2001) and is supported by findings that indicate infant language skill is negatively correlated with caregiver response time to vocalizations (Gilkerson, Richards, & Dongxin, 2012).

Utterances were coded as semantically responsive if they '*followed*' the infant's focus of attention. This was considered to be the case if the utterance referred to an object that the child was holding, was looking at, or had referenced by a point or give gesture, or if the utterance was related to the activity in which the child was already engaged (Akhtar et al., 1991; Carpenter et al., 1998, p. 56). For this measure, the presence of an infant vocalization alone was not considered sufficient to indicate attention to an object or engagement with an activity. The number of semantically responsive utterances was divided by the total number of maternal utterances to produce a proportional semantic contingency score for each parent.

Temporal contingency: The number of times the caregiver produced an utterance in the 2 second window following an infant vocalization was calculated using ELAN's built in search function. If caregivers produced more than one utterance within 2 seconds of an infant vocalization, only the first utterance was considered as temporally responsive to the infant vocalization. In addition to calculating the raw number of temporally contingent utterances, we also calculated two proportional measures. The first measure controls for overall amount of adult speech and was calculated as the number of temporally contingent utterances divided by the total number of maternal utterances. The second controls for overall amount of infant vocalizations and was calculated as the number of temporally contingent utterances divided by the total number of infant vocalizations.

Semantic and temporal contingency: A composite measure representing the number of times that the caregiver had responded in a semantically appropriate way within 2 seconds of an infant vocalization was calculated using ELAN's built in search function. The number of utterances fulfilling this criterion was divided by the total number of maternal utterances to produce a proportional measure for each dyad.

Demographic Measures

Demographic measures were obtained from a questionnaire that parents completed on the first home visit at 9 months. Gender and birth order were coded as binary variables. Maternal education was coded on a 5-point scale following a modified version of Hobbs & Vignoles' (2007) classification system (1: No qualifications; 2: vocational qualifications; 3: GCSE or equivalent; UK exams typically taken at 16 years of age; 4: A 'levels or equivalent; UK exams typically taken at 18 years of age; 5: Degree). 70% of mothers had a university degree.

Outcome Measure

A parental report instrument, the MacArthur Bates Communicative Development Inventory (CDI; Hamilton, Plunkett, & Schafer, 2000) was used to obtain the infant's *expressive vocabulary* at 18 months (Mean age at collection = 559 days; Range = 513 – 592; 79 days).

Reliabilities

Reliabilities for the phonetic transcription of infant vocalizations were calculated as part of the original study on four randomly selected 3-minute video clips. These segments were transcribed by all three transcribers and reliabilities calculated in terms of the percentage agreement between every two transcribers. Average agreement for the transcription of supraglottal consonants was 69% (range 65%-72%; DePaolis & Keren-Portnoy, under review) although this rose to 80% (range 76% to 89%) when infrequently used consonants /l/ and /s/ were not included. This degree of agreement is in line with similar studies of pre-linguistic babble (McCune & Vihman, 2001). It is however, important to note that this study considered the occurrence of a vocalisation as a measure of interest (rather than the precise phonological nature of these vocalizations). The first author re-checked each recording to ensure all infant vocalizations had been accurately marked.

To check the reliability of the semantic contingency measure (note that temporal contingency was calculated automatically) a trained research assistant independently coded 22% of the sample (10/46) randomly selected from the complete group. Cohen's Kappa was .84 indicating very good agreement. All disagreements were discussed with the first author and resolved.

III. RESULTS

Below, we first consider the control measures of quantity of maternal speech and infant vocalizations and maternal education, checking for correlations between them. Having selected three representative control measures to take forward, we then report a series of regression models that investigate the relationship between the four responsiveness measures and expressive vocabulary development at 18 months.

As there were no effects of gender or birth order on expressive vocabulary (Gender: t (44) = .392, p=0.135); Birth Order: t(44) = 1.287, p = 0.205) at 18 months, these variables were not included in any further analysis.

Controlling for IDS and Infant Volubility

Caregivers showed substantial variation in the quantity of infant directed speech produced during the 10 minutes of dyadic interaction. Some mothers produced almost eight times as many words or three times as many different word types as others. Individual differences are also apparent in the vocal behavior of the infants, with some barely vocalizing at all, whilst others vocalized up to 15 times per minute. Descriptive statistics for all infant directed speech and infant vocalisation measures are presented in Table 1.

As can be seen in Table 2, mothers who talked more to their infant also produced more different types of words, used longer utterances and spoke more quickly. Maternal education was not related to any measure of maternal or infant vocal behavior. Having considered the inter-correlations between measures of infant directed speech, and bearing in mind our sample size and the power it afforded, we retained vocabulary diversity VOCD as a representative measure of IDS and we used this as a control in the following regression models alongside maternal education and the number of times the infant vocalized. The pattern of results reported below remains the same if a different control measure of maternal speech is used.

[Insert Tables 1 & 2 about here]

Exploring the Internal Structure of Responsiveness and its Relationship to Vocabulary Development

Mothers tended to use semantically appropriate speech when talking to their infants but only responded to vocalizations in a semantically and temporally appropriate manner on average 6% of the time (one infant did not vocalize in the 10 minutes of interaction resulting in zero measures for temporal measures of contingency). Descriptive statistics for all responsiveness measures are presented in Table 3 (See Appendix: Table 1 for descriptive statistics for all raw contingency counts) Correlation matrices describing relationships between all dimensions of responsiveness, control and outcome measures are presented in the Appendix (Table 2: Raw counts; Table 3: Proportional counts).

[Insert Table 3 about here]

To explore whether semantic contingency predicted expressive vocabulary at 18 months, we built the regression model presented in Table 4. When controlling for infant vocalizations, maternal education and vocabulary diversity, the proportion of maternal speech that is semantically responsiveness is not a significant predictor of expressive vocabulary at 18 months.

[Insert Table 4 about here]

Exploring whether temporal contingency predicted expressive vocabulary at 18 months was more difficult to do while controlling for infant vocalizations since temporal responsiveness measures were highly positively correlated with the number of times the infant vocalized (this is a straightforward consequence of how temporal responsiveness was operationalised as a response to an infant vocalisation). Given these strong correlations, infant vocalizations could not be included in the regression models as a control measure. To explore the extent to which infant vocalizations, rather than responsiveness per se, could predict vocabulary at 18 months, we first fit the model with the maternal control measures and number of infant vocalizations alone to the data (Table 5). This demonstrated that number of infant vocalizations was not in itself a good predictor of later vocabulary.

[Insert Table 5 about here]

We then explored fitting similar models to the data, replacing infant vocalizations with measures of temporal responsiveness. As mentioned previously, temporal responsiveness can either be calculated as the proportion of maternal utterances that were produced within two seconds of an infant vocalisation (see Table 6) or it can be calculated as the proportion of infant vocalisation that were responded to within 2 seconds (see Table 7). Neither measure, however, was found to be a significant predictor of language outcomes.

[Insert Tables 6&7 about here]

The temporal and semantic responsiveness measure was calculated as the proportion of maternal utterances that were both produced in response to an infant vocalisation and semantically related to the infant's focus of attention. As can be seen from Table 8, once maternal education and vocabulary diversity are controlled for, the measure of temporal and semantic responsiveness was a significant predictor of vocabulary at 18 months.

[Insert Table 8 about here]

IV. Discussion

This study investigated the relationship between semantic and temporal dimensions of maternal responsiveness in dyadic interaction at 9.5 months and the infant's vocabulary level at 18 months. The primary goal was to understand more fully the basic elements of verbal responsiveness, and determine which are most helpful for language learning. Taking into account measures of the quantity of IDS, maternal education and infant vocalizations, we found that only utterances that were both semantically appropriate and temporally linked to an infant vocalisation related to infant expressive vocabulary at 18 months. This measure captures the ability of the dyad to engage in 'proto-conversations' and as such relies on an infant vocalizing and a caregiver 'translating' that vocalisation into conventional language. It is easy to imagine why this type of exchange would be especially conducive to learning. Not only is the language produced by the parent about what the child is attending to, but it is also produced in response to a communicative act on the part of the child.

One might question whether the vocalizations produced by these 9-month-olds were truly communicative. At the very least, we can say that they are a salient cue that tends to elicit responses from parents (Gros-Louis, West, Goldstein, & King, 2006). Acknowledging this is not to attribute communicative intentionality in the traditional sense to the infants' vocalizing. Instead, it may be that parent's responses (which treat vocalizations as communicative) shape infants vocalizations into a truly communicative behavior that they have intentional control over. Infant vocalizations can thus be seen not only as indicators of interest or attention but as a signal of readiness to learn *that* and *how* we communicate about the external world. This represents a fertile area for future research, especially in this developmental timeframe, just before the onset of referential gestures including pointing (between 9 and 12 months).

Given the literature on semantic responsiveness, it is surprising that we did not find this measure alone to be a good predictor of vocabulary. This may be because the level of semantically contingent speech was globally relatively high in this sample, perhaps due to an artefact of the video recording protocol. Parents were asked to play with their infants and adhering to this instruction necessitated that the mother attended to what their infant doing (Ninio & Snow, 1996). Alternatively, this inconsistency could be due to our choice of control variables, or our decision to code all caregiver speech and not adopt an events analysis approach (Bornstein et al., 2008). Finally, it could be that measuring contingent talk as a proportion of total talk (rather than as a raw count) explains the lack of correlation between this measure and vocabulary scores (although many previous studies have also used the proportional measure). Raw semantic contingency counts (see Appendix 1) were highly correlated with measures of infant directed speech. Proportional values were therefore favored, both to normalize the amount of infant directed speech across participants, and to avoid collinearity in our final regression models.

Theoretically, there would be good reason to think that both the raw frequency of contingent utterances and the proportion of them (relative to other utterances) could be good predictors. First, one could predict that raw frequency alone should be important since every contingent utterance represents an opportunity for language learning. Second, the relative amount of contingent speech to other speech could also be seen as important in the sense that it reflects a better signal to noise ratio. A lack of non-contingent words could thus avoid infants at this very early stage of word learning making spurious associations and could potentially make language learning more salient and rewarding. However, far too little is known about lexical development at this early point to be able to decide between these speculations and furthermore, it is possible that the effects of the amount and the relative proportion of contingent speech may vary longitudinally. High levels of inter correlation between raw contingency counts and other measure of IDS mean that we cannot begin to answer these questions with this dataset. To develop a more nuanced understanding of these issues will require further research drawing on larger samples with more variance in child directed speech. We are currently exploring the effect of an intervention to increase the amount of contingent talk infants hear just before their first birthday to test for a potential causal role in language development.

For the moment, the current findings suggest that for semantically contingent talk to be useful to the novice language learner it must occur within a temporal window where the infant is not only engaged with an activity or object but is also ready to communicate. There are of course many ways that infants can indicate this in the course of an interaction. This study would suggest that, at 9 months, early vocalizations are a good indicator. As infants begin to point, gestures will become another. There is good evidence that adults respond to infant pointing (Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007) and that it predicts later vocabulary (Rowe & Goldin-Meadow, 2009). What appears to be key at this early stage, though, is that the most fertile ground for language learning is found when a caregiver takes an act on the part of the infant to be communicative and responds with the words that infant would need to know to be able to participate in a conventional exchange.

APPENDIX

[Insert Appendix Tables 1- 3 here]

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Table 1: *Descriptive Statistics for Maternal Speech Measures and Infant Vocalisations at 9.5 months (N= 46)*

	Minimum	Maximum	Mean	SD
Number of maternal word tokens	119	938	450.22	189.114
Number of maternal word types	61	280	155.96	48.049
Maternal Mean Length of Utterance (MLU; in morphemes)	2.976	6.352	4.727	.700
Maternal Vocabulary diversity (VOCD)	26.290	100.340	66.700	17.510
Maternal Speech density (milliseconds)	832.921	1605.686	1168.301	168.675
Number of infant vocalizations	0	159	51.22	40.697
Maternal education	2	5	4.53	.809

Table 2: *Correlation Coefficients (Pearson's r) among Infant and Maternal Speech Measures (N=46)*

	Tokens	Types	MLU	VOCD	Speech density	Infant Voc's	Maternal Education
Tokens							
Types	.914**						
MLU	.317*	.302*					
VOCD	.561**	.797**	.289.				
Speech density	.343*	.379**	.533**	.457**			
Infant Voc's	-.151	-.113	-.228	-.016	-.415**		
Maternal Education	.028	-.103	-.074	-.270	-.086	.204	

** $p<0.05$; ** $p<0.01$*

Table 3: *Descriptive Statistics for Responsiveness Measures (N= 46)*

	Minimum	Maximum	Mean	SD
Semantic contingency	.1955	.6639	.450	.114
Temporal contingency (as proportion of maternal utterances)	0	.509	.146	.124
Temporal contingency (as proportion of infant vocalizations)	0	1.00	.472	.251
Semantic and temporal contingency	0	.217	.064	.055

Table 4: *Regression model fitting Semantic Contingency and Control measures to Expressive Vocabulary at 18 months*

	B	***T***	***p***
Semantic contingency	.110	.765	.448
Infant Vocalisations	.241	1.651	.106
Maternal Education	.176	1.178	.245
VOCD	-.255	-1.761	.086

R^2 =.126., $F(1,44) = 2.620$, $p = .049$

Table 5: *Regression model fitting Infant vocalizations and Control Measures to Expressive Vocabulary at 18 months*

	B	***T***	***p***
Infant Vocalisations	.217	1.531	.133
Maternal Education	.194	1.317	.195
VOCD	-.250	-1.733	.090

R^2 =.134 ., F(3,42) = 3.331, p = .028

Table 6: *Regression model fitting Temporal Contingency (as a proportion of maternal utterances) and Control Measures to Expressive Vocabulary at 18 months*

	B	***T***	***p***
Temporal contingency	.035	.239	.812
Maternal Education	.231	1.503	.140
VOCD	-.245	-1.643	.108

R^2 =.087., F(3,42) = 2.437, p = .078

Table 7: *Regression model fitting Temporal Contingency (as proportion of infant vocalizations) and Control measures to Expressive Vocabulary at 18 months*

	B	***T***	***p***
Temporal contingency	-.221	-1.565	.125
Maternal Education	.259	1.751	.087
VOCD	-.233	-1.587	.120

R^2 =.198., F(1,44) = 3.370, p = .027

Table 8: *Regression model fitting Semantic & Temporal contingency and Control Measures to Expressive Vocabulary at 18 months*

	B	***T***	***p***
Semantic & Temporal contingency	.341	2.414	.020
Maternal Education	.133	.915	.366
VOCD	-.232	-1.672	.102

R^2 = .198., F(3,42) = 4.692, p =.006

Appendix Table 1: *Descriptive statistics for Raw Maternal Speech and Contingency counts (N=46)*

	Minimum	Maximum	Mean	SD
Infant Directed Speech	45	288	158.52	51.958
Semantic Contingency	17	141	71.04	28.852
Temporal Contingency	0	115	23.65	24.650
Semantic & Temporal Contingency	0	49	10.33	10.533

Appendix Table 2: *Correlation Coefficients (Pearson's r) among Raw Responsiveness counts and Expressive vocabulary at 18months*

	Semantic Contingency	Temporal Contingency	Semantic & Temporal Contingency	Expressive Vocabulary
Semantic Contingency				
Temporal Contingency	.258			
Semantic & Temporal Contingency	.392**	.932**		
Expressive Vocabulary	-.295*	.083	.188	1

* p<0.05; ** p<0.01;

Appendix Table 3*: Correlation Coefficients (Pearson's r) among proportional Responsiveness, Control and Outcome Measures*

	Semantic Contingency	Temporal Contingency (maternal utterances)	Temporal Contingency (infant voc's)	Semantic & Temporal Contingency	VOCD	Infant voc's	Maternal Education	Expressive vocabulary at 18 months
Semantic Contingency								
Temporal Contingency (maternal utterances)	.011							
Temporal Contingency (infant voc's)	.183	.232						
Semantic & Temporal Contingency	.201	.917**	.275					
VOCD	.012	-.079	.037	-.110				
Infant voc's	-.182	.895**	-.055	.764**	-.016			

Maternal Education	.102	.243	.105	.322*	-.270	.204	
Expressive vocabulary at 18 months	.081	.275	-.202	.409**	-.306*	.261	.306*

* p<0.05; ** p<0.01;