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Maternal speech to infants at 1 and 3 months of age

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Abstract

The goal of this study was to assess maternal speech and in relation to changes in infant social behavior occurring around the second month post birth. Sixty infants interacted with their mother at 1 and 3 months of age in a face-to-face context. At 3 months, infants gazed, smiled, and positively vocalized significantly more than at 1 month. These findings point to a transition in infant social behavior at around the second month post birth. In addition, maternal speech to infants increased between these times in both amount and complexity, possibly in response to an increase in infant social behavior. Maternal speech was related to infant positive vocalizing at 3 months, suggesting mothers especially monitored infant vocalizing at 3 months. Individual differences in maternal speech were stable across visits.

Keywords: Maternal speech; Two-month transition; Infant-directed speech; Face-to-face interaction

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1. Interaction

The word “infant” means “one who is unable to speak”. Yet, despite infants’ inability to speak, adults in many cultures engage in prolonged “conversation-like” interactions with them, and respond verbally to their nonverbal sounds (Bateson, 1975). In these early exchanges, adults use a variety of linguistic and paralinguistic alterations (e.g., Ferguson, 1964; Garnica, 1977; Stern, Spieker & MacKain, 1982). These features of infant-directed (ID) speech are likely an adjustment to infant development as they capture infants’ perceptive, attentional, and affective predispositions (e.g., Cooper & Aslin, 1990; Fernald, 1993; Papousek & Papousek, 1981; Pegg, Werker & McLeod, 1992; Sullivan & Horowitz, 1983). Also, there is evidence that maternal speech varies as a function of infant factors like age and communicative abilities (e.g., Broerse & Elias, 1994; Kitamura & Burnham, 2003; Stern et al., 1982), suggesting that the use of ID speech is motivated by a desire to feel in communication with the infant (Brown, 1977; Snow, 1977).

Overall, prior research suggests that maternal speech to preverbal infants is attuned to infant behavioral and affective state and should be influenced by infant behavioral feedback on quality of interpersonal engagement. To test such idea, Murray and Trevarthen (1986) had mothers interact face-to-face with their 2-month-old infants over a video system, and compared maternal speech in a live interaction with one where mothers interacted with a replay of the infant. In live interactions, when mutual responsiveness was possible, maternal speech was more child-centered, “contentless”, and repetitive, and contained more interrogatives than during replay sessions. The authors argue that this increase in ID speech features was related to occurrence of mutual responsiveness. These findings suggest that if ID speech has a primarily communicative function, then mothers should increase ID speech features in relation to infant social engagement also in natural face-to-face interaction.

According to Rochat and Striano (1999), primary intersubjectivity, i.e., mutual responsiveness and sharing of affect (Trevarthen, 1979), emerges by 2 months of age, when major changes occurring in infant social development enable infants to start to reciprocate in dyadic interaction. By the end of the second month, opportunities for dyadic exchanges increase as infants spend considerably more time in an alert-awake state (Wolff, 1987), and looking at their mother’s eyes (Haith, Bergman, & Moore, 1977; Maurer & Salapatek, 1976). Importantly, social smiling emerges around this time (Robson & Moss, 1970) as well as first voiced pleasure sounds (cooing), which are most likely to occur in social interaction with adults, and especially in the presence of a smiling and nodding face (Stark, 1978, 1980). Consistent with the idea of a transition in infant social behavior occurring around the second month of age, Kaye and Fogel (1980) reported an overall increase between 1.5 and 3 months for infant responsiveness to the mother in face-to-face interaction. More recently, Lavelli and Fogel (2005) documented the development of the relationship between infant attention and emotion expressions in face-to-face interaction with their mothers across the first 3 months of life. Whereas during the first month, infants mostly gazed at their mother’s face without any sign of emotional engagement, infant visual attention started to be associated with emotion expressions such as effortful concentration and smiling during the second month and, during the third month, more active and approaching patterns of attention and emotion dominated in dyadic interaction, including excited attention and cooing expressions.

This increase in the infant’s ability to engage and reciprocate in dyadic interaction likely relates to qualitative changes in caregiver–infant interaction. In fact, mutual influence between infant and maternal behavior increases across the first 3 months (Lavelli & Fogel, 2005), and maternal and infant vocal behavior are temporally coordinated at 3.5 months (Beebe, Alson, Jaffe, Feldstein, & Crown, 1988; see also Jaffe, Beebe, Feldstein, Crown, & Jasnow, 2001). Also, when infants start reciprocating with smiling,

caregivers report to have discovered the person in their infants (Robson & Moss, 1970; Rochat & Striano, 1999; Wolff, 1987). The emergence of more active and approaching patterns of attention and emotion such as cooing (Lavelli & Fogel, 2005) might have a similar effect on caregiver's perception of their infant as having become more able communicators, given also that adults perceive cooing sounds as more communicative than other, less speech-like, infant sounds (Beaumont & Bloom, 1993).

Overall, the findings reviewed above on maternal speech adjustments to infant communicative abilities suggest that this increase in the infants' ability to engage in mutual responsive interactions might be reflected in maternal speech. Prior research on maternal speech to preverbal infants mainly focused on prosodic and semantic adjustments to infant age and interactional context (e.g., Kitamura & Burnham, 2003; Stern, Spieker, Barnett, & MacKain, 1983). Kitamura and Burnham (2003), for example, suggested that an increase in maternal pitch and expression of communicative intent at 3 months compared to neonates, related to an emerging social responsiveness of the infant. To our knowledge, however, there has been no study reported in which maternal linguistic input to infants has been assessed at 1 and 3 months of age, i.e., with reference to an increase in infant social responsiveness around the end of the second month. Thus, the goal of the current study is to assess both infant social behavior and maternal linguistic input at 1 and 3 months as well as relations between maternal linguistic input and specific infant behavior at each age point.

Based on prior research (e.g., Kaye & Fogel, 1980; Lavelli & Fogel, 2005), we expected to find an increase in infant social behavior such as visual attention to the mother's face, smiling and positive vocalizing at 3 compared to 1 month. Given an increase in stability of infant state around the second month (Wolff, 1987), we also expected a decrease in infant fussiness, as indexed by a decrease in negative vocalizing at 3 months.

In Western industrialized cultures mothers generally treat their infants as interlocutors from early on (Kaye, 1982; Trevarthen, 1979; see also Lieven, 1994). However, at 3 months, when infant attention is more easily elicited, maintained, and accompanied by emotion expressions, and when infants are more active and socially responsive partners in interaction and produce more speech-like sounds such as cooing (e.g., Lavelli & Fogel, 2005; Stark, 1980), mothers may well perceive their infants as having become more communicative and more able interlocutors. We, therefore, expected an overall increase in the amount and diversity of maternal speech at 3 compared to 1 month. Specifically, at 1 month, when infant attention is still fleeting and their emotional state instable (Wolff, 1987), mothers should mainly be concerned with eliciting infant attention and preventing fussiness. With an increase in the infant's ability to engage in social interaction, we thus expected an increase in maternal speech rate (more words and utterances per minute) at 3 compared to 1 month as well as relatively more complex speech, indexed by a longer mean length of utterance (MLU), i.e., more words per utterance, and by greater lexical diversity, i.e., a greater number of different words used during the 3-min interaction. Also, at 3 months, mothers might attempt more persistently to involve the infant in the conversation by eliciting turn taking, indexed by an increase in interrogative utterances, e.g., questions and utterances with a rising intonation contour at 3 months (Papousek, Papousek, & Symmes, 1991). Similarly, when talking to 3- compared to 1-month-olds, mothers might use more "phatics", i.e., utterances consisting of a single word, filler or sound, e.g., *hi*, *yes*, and *oh* (Kaye, 1980). According to Kaye (1980, 1982), these one-word-utterances are characteristic of speech to young infants and usually used in response to infant attention or expressive action either as acknowledgements of real communications of the infant or when mothers pretend the infant has the floor.

In terms of the relation between infant behavior and maternal speech, to our knowledge, few studies assessed the relation between preverbal infant behaviors and maternal speech variables such as number

and mean length of utterance, and never longitudinally at 1 and 3 months. Prior research on the preverbal period mainly assessed relations between maternal verbal behavior and various infant behaviors in terms of occurrence, temporal patterning, and contingency. For example, Beebe et al. (1988) reported temporally coordinated mother–infant vocal interaction by 3.5 months, Hsu and Fogel (2003) showed that 1–6-month-old infants' non-distress vocalizing reliably elicited maternal verbal response, and Lavelli and Fogel (2005) reported an increase in sequential linkages between maternal talking and infant behaviors across the first 3 months. Whereas Kaye (1980) did not find significant relations between maternal language input and infant behaviors at 1.5, 3, and 6 months (derived by Kaye & Fogel, 1980), Mayer and Tronick (1985) reported negative correlations between infant responses and total number of maternal utterances and questions at 3 but not at 2 months. Given the research reviewed in this work, we also assessed the relations between single infant social behaviors and maternal speech measures at each age point. However, given the somewhat controversial findings regarding relations between specific infant behaviors and maternal linguistic measures, we only advanced the relatively general prediction that maternal speech would be more systematically related to infant social behavior at 3 months than at 1 month.

Finally, Kaye's findings (1980) showed that individual differences in content, length and repetitiveness of maternal utterances were stable at 1.5, 3, and 6 months of age, regardless of infant gender and maternal education. Based on these findings, we expected to find similar stable individual differences in mothers' speech to their infants at 1 and 3 months.

2. Method

2.1. Participants

Sixty infants participated (27 males and 33 females). They were seen at 1 (M = 37.77 days, S.D. = 4.65, range = 30–50 days) and 3 months (M = 105.87 days, S.D. = 4.35, range = 97–121 days). An additional four infants were excluded because they missed a session. All infants were full-term and had a 1 and 5 min Activity, Pulse, Grimace, Appearance, and Respiration (APGAR) score of 7 or higher. Participants were predominantly Caucasian and from middle-class backgrounds. Maternal education was assessed according to whether mothers had higher education (53.3%) or not (46.7%). Higher education was defined as having successfully completed the "Gymnasium" or "EOS", which equals 12–13 years of schooling and receiving the diploma "Abitur". Infants were recruited from a small city hospital where a research assistant visited mothers at the time of the birth. The same research assistant later contacted the mothers by telephone to invite them to take part in the study. Infants received a toy at each visit for their participation. Caregivers received a videotape of the sessions and travel expenses.

2.2. Set up and procedure

Testing took place in a laboratory room within an area surrounded by white curtains to eliminate any possible distractions. Infants sat in a commercial infant seat (with a 30° back rest tilt) placed on a low table. Mothers sat on a stool facing their infants, approximately 40 cm apart from them. This seating arrangement allowed for easy eye contact between the dyad. Four digital video cameras (Sony DCR-TVR 11E) provided a front close-up view of the infant, a front close-up view of the mother, a side view of the dyad, and another close-up view of the infant. The four images fed into a digital quad (Panasonic WJ-MS 424) connected to a digital VCR (Sony GV-D900E PAL) that recorded image and sound for later

coding. Mothers had a microphone attached to their clothes on the upper front part of their torso. In both visits infants interacted 3 min with their mother in a face-to-face context. Mothers were asked to interact normally and to refrain from touching their infant. Some interactions were interrupted because infants became fussy, and therefore proportional scores were used in all cases.

2.3. Coding

2.3.1. Infant behavior

An observer, blind to the hypotheses of the study, used a computerized coding system (Interact 6.8) (Thiel, 2002) to code infant gazing, smiling, and vocalizing. Coding was done in real time. While viewing the video recording, the coder pressed a key of a computer that corresponded to a specific behavior when she judged this behavior to be present, and she released the key at the behavior's off-set. Thus, coding pertained to the occurrence of infant behavior as follows:

(a) Infant gazing: visual attention to the mother's face. We also calculated the average length of a single gaze bout for each infant by dividing the total duration in seconds by frequency of infant gazing.
(b) Infant smiling: raised cheeks and corner of lips turned up regardless of mouth opened or closed. Given that social smiling emerges during the second month of life (e.g., Wolff, 1987), we also counted number of infants that smiled at all during the interaction at each visit.
(c) Infant positive vocalizing: vocalizations subjectively perceived as positive in hedonic tone. Following prior research (e.g., Hsu & Fogel, 2003; Stark, 1978) vegetative sounds (such as coughs, sneezes, hiccups, yawns, sighs, clicking and tongue-play sounds) and effort sounds (sounds accompanying effortful actions, e.g., when the infant tries to pull herself up) were excluded.
(d) Negative vocalizing: vocalizations subjectively perceived as negative in hedonic tone and/or with a protest-like quality (such as fussing, whining, crying, and screaming), excluded vegetative and effort sounds (see above).

For infant vocalizing, two separate sounds were recorded, if the sound was segmented by a perceivable silence (see e.g., Hsu & Fogel, 2003). Coders had to judge (1) whether an infant sound was present or absent, (2) whether this sound was or was not a vegetative or effort sound, (3) and whether the sound was positive or negative in hedonic tone. Given that these were the only parameters relevant to the current work, and given the evidence that adult listeners are able to infer speech production processes and underlying emotional states in vocal sounds (Scherer, 1982), we used auditory perceptual assessment by a human observer for infant vocalizations instead of objective methods such as, e.g., phonetic or acoustic analysis (e.g., Stark, 1980). At 1 month, data points for one infant's positive and negative vocalizing were missing due to bad quality of sound, and therefore substituted by mean replacement.

To assess intercoder reliability, a second coder scored a random 25% of the sessions. Cohen's Kappas were calculated using a computerized program (Interact 6.8) (Thiel, 2002). With a 1-s accuracy interval, Cohen's Kappas for visit 1 were 0.84 for infant gazing, 0.80 for smiling, and 0.63 for infant vocalizing, and Kappas for visit 2 were 0.84 for infant gazing, 0.95 for smiling, and 0.72 for infant vocalizing[1].

[1] Infant vocalizing pertained to one coding category, with different codes corresponding to positive or negative valence. Hence the single reliability score for infant vocalizing. All Kappas reported were calculated using a computerized program (Interact 6.8) (Thiel, 2002) that takes frames in addition to seconds in account. Thus computed, Kappa for infant vocalizing at visit 1 is below 0.7, but when calculating Kappa by hand, with a 1-second accuracy level, and taking only full seconds in account,

2.3.2. Maternal speech

Maternal speech was transcribed by a second coder using the transcription rules in the Child Language Data Exchange System (CHILDES, see e.g., MacWhinney, 2000). CHILDES is a public domain database for corpora on first and second language acquisition that stores acquisition data in a specific format, the Conventions for Human Analysis of Transcripts (CHAT), which is compatible with the tools for data analysis of the Child Language Analysis (CLAN) programs. All meaningful communicative vocalizations were considered as words, i.e., also fillers and sounds such as *hm*, *oioioi*, and *oh* (these fillers and sounds were marked as such), and were transcribed in the mother's speaker tier according to the CHAT format as shown in Appendices A and B. Kisses, tongue clicking and routines (e.g., songs) were excluded from the speaker tier but annotated as paralinguistic information (see also Kaye, 1980; Stern et al., 1982). Maternal speech was transcribed according to German orthographic standard, also applied to maternal word creations such as nicknames (e.g., "hasenkind" – in English "bunnybaby"), but with the exception that all words were transcribed in lower case only as upper/lower case did not matter to the questions of this study. Any variation of a word pertaining to dialect or colloquial speech was transcribed as such if it appeared in the Wortschatz Database at the University of Leipzig (an on-line German lexicon)[2]. For example, *heut* and *heute* (meaning both *today*) both appeared in this database and were thus considered as different words. Otherwise transcription followed German orthographic standard. Omission of words was not corrected, e.g., the verb *ist* was not inserted in the utterance *was [] da?* (*what [] there?*). Omitted syllables or phonemes were substituted with an apostrophe in the case of clitics, e.g., *wenn 's* for *wenn es* (*if it*), or *so 'ne suesse* for *so eine suesse* (*such a sweet one*). Utterance boundaries were defined by pause segmentation and intonation information. Thus an utterance, i.e., a "tier" according to CHAT format, was defined as a segment of speech and/or sounds preceded and followed by an auditory pause (e.g., Kitamura, Thanavishuth, Burnham, & Luksaneeyanawin, 2002), and hence without interruption of the intonation contour. Utterances could thus be composed of one or more sentences, a phrase, a sentence fragment, or a single sound or word (see e.g., Kitamura & Burnham, 2003). Subsequently, using the search functions of the CLAN programs, the transcripts were searched for the following speech variables:

(a) Mean length of utterance (MLU): ratio of words to utterances (e.g., Kaye, 1980; Phillips, 1973).
(b) Utterance rate: utterances per minute (e.g., Kaye, 1980; Phillips, 1973).
(c) Token rate: number of words per minute. Given the relative short recordings of 3 min, and the variable length of utterances, token rate was used as additional measure indexing amount of speech.
(d) Vocabulary diversity (VOCD): VOCD is a measurement of vocabulary diversity that takes into account that larger numbers of tokens in the transcript give lower values for TTR (type-token ratio) and vice versa. This CLAN program analyzes the probability of new vocabulary being introduced with an increase in sample size and bases the measure on the TTR versus token curve calculated from data for the transcript as a whole (MacWhinney, 2000); fillers and sounds, were excluded for the computation of VOCD.
(e) Interrogatives: percentage of interrogative utterances on total number of utterances. Interrogative utterances were defined as utterances with rising pitch contour and/or use of word order and gram-

Kappa is 0.94, and coders only disagreed on 8 out of 300 events. This disagreement pertained to presence/absence of event, not to positive/negative valence. Also, there was a strong correlation between percent of time between the two coders (Pearson's correlation: $r = 0.981$, $p < 0.001$, and $r = 0.996$, $p < 0.001$, for infant positive and negative vocalizing respectively). In both cases mean differences between coders were less than 0.14%.

[2] Wortschatz-datenbank of the University Leipzig at http://wortschatz.uni-leipzig.de.

matical markers of questions, i.e., yes–no questions and wh-questions. Interrogative utterances were transcribed as "tiers" (i.e., utterances) terminating with a question mark.

(f) One-word-utterances: percentage of utterances composed by a single word, filler, or sound on total number of utterances (see Kaye, 1980,1982). Most one-word-utterances mothers produced were fillers and sounds, e.g., *hm*, *ah* and *oh* ($M = 39.2$ and 38.0% at visits 1 and 2, respectively) and the word *ja*, meaning *yes* ($M = 31.8$ and 30.5% at visits 1 and 2), followed by addressing the infant, e.g., by name or nickname ($M = 6.7$ and 8.5% at visits 1 and 2) and greetings such as *hi* ($M = 6.3$ and 8.0% at visits 1 and 2). Mean percentages of one-word-utterances with rising intonation were 34.5 and 41.8% at visits 1 and 2, respectively.

3. Results

3.1. Infant behavior

Preliminary analyses on infant measures yielded no significant main effects or interactions for infant gender, all ps > 0.05. Thus, this variable was collapsed in the subsequent analyses on infant behavior.

To assess whether there were differences in amount of infants' social behavior at 1 month compared to 3 months, we performed repeated measures Analyses of Variance (ANOVA) with age as within-subjects factor on the percent of time infants gazed, smiled, and vocalized positively and negatively at their mothers during the interaction. Also, to assess whether infant gaze bouts to their mother were longer at 3 compared to 1 month, we performed a repeated measures ANOVA with age as within-subjects factor on the mean duration of individual gaze bouts. Finally, to assess whether more infants smiled at their mothers at 3 compared to 1 month, we performed an exact McNemar test on number of infants that smiled at 1 compared to 3 months. To correct for multiple testing, we adjusted the p-values for the six tests on infant behavior using Hochberg's improved Bonferroni method (Shaffer, 1995). Adjusted p-values are reported here. A null hypothesis was rejected at an α-level of 0.05. All means are presented in Table 1.

Analyses revealed a main effect of infant age on infant gazing, $F(1, 59) = 10.80$, $p < 0.01$, on infant smiling, $F(1, 59) = 15.95$, $p < 0.001$, and on infant positive vocalizing, $F(1, 59) = 13.80$, $p < 0.01$. Confirming our predictions, infants gazed and smiled significantly more at 3 months compared to 1 month, and also produced significantly more positive vocalizations at 3 months. In addition, the mean length of individual gazing bouts increased significantly between 1 and 3 months, $F(1, 59) = 6.52$, $p < 0.05$. A trend indicated that infants also produced less negative vocalizing at 3 months than at 1 month, $F(1, 59) = 3.58$, $p = 0.06$. Finally, an exact McNemar test revealed that the number of infants that smiled at all during interactions significantly increased at 3 months compared to 1 month, $p < 0.001$. Whereas only 55% of infants smiled at their mothers during interaction at 1 month, 92% smiled at 3 months.

3.2. Maternal speech

Our next question was whether maternal speech to infants at 1 month differed from their speech when infants were 3 months old. Based on prior research documenting differences in maternal speech related to social class (e.g., Tulkin & Kagan, 1972), maternal education was 0–1 dummy coded according to whether mothers had higher education or not, and included as additional factor in the preliminary analyses on maternal speech measures. Preliminary analyses yielded no significant main effects or interactions for

Table 1
Maternal speech and infant behavior: means and standard deviations at 1 and 3 months

	1 month		3 months	
	M	S.D.	M	S.D.
Mother				
MLU	3.67	1.18	4.00	0.88
Utterance rate	24.77*	5.36	26.54	5.71
Token rate	90.00*	28.92	101.03	24.34
VOCD	75.71***	27.38	88.22	26.00
Interrogatives (%)	32.90	15.74	36.73	14.36
One-word-utterances (%)	36.69	14.24	33.91	12.58
Infant				
Gazing (%)	52.49**	29.25	70.21	27.32
Gaze bout (sec)	14.15*	24.11	34.61	53.59
Smiling (%)	3.51***	6.44	9.10	10.50
Smiling infants (%)	55.00		91.67	
Positive vocalizing (%)	2.68**	2.99	7.26	8.85
Negative vocalizing (%)	2.65	6.20	0.90	3.19

Smiling infants refers to the percentage of infants that smiled at all during the interaction at 1 and 3 months. MLU = mean length of utterances; VOCD = vocabulary diversity.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

infant gender or maternal education, all ps > 0.05 (Hochberg–Bonferroni adjusted). Thus, these variables were collapsed in the subsequent analyses.

To assess whether maternal speech differed between visits, we then conducted a repeated measures ANOVA for each maternal speech measure as dependent variable and with infant age as within-subjects variable. To correct for multiple testing, we adjusted the p-values for the six tests on maternal speech using Hochberg's improved Bonferroni method (Shaffer, 1995). Adjusted p-values are reported here. A null hypothesis was rejected at an α-level of 0.05. The means for all maternal speech measures are presented in Table 1.

Analyses revealed a main effect of infant age on utterance rate, $F(1, 59) = 6.91$, $p < 0.05$, on token rate, $F(1, 59) = 10.95$, $p < 0.05$, and on vocabulary diversity, $F(1, 59) = 17.02$, $p < 0.001$. Mothers produced more utterances and more words when infants were 3 compared to 1 month old, and also maternal vocabulary was richer when infants were 3 compared to 1 month old. There were no significant differences between age groups for MLU, interrogatives, and one-word-utterances, all adjusted ps > 0.05.

3.2.1. Relations between infant behavior and maternal speech at 1 and 3 months

To assess whether a specific maternal speech measure was related to a specific infant behavior at each age, we performed for each visit a series of multiple regressions for each maternal speech variable as dependent measure, and with the following five independent variables: infant gazing, smiling, positive and negative vocalizing in percent of time and maternal education. For each dependent measure and at each age point, multiple regressions were performed using the following model selection methods: step-wise, step-wise backward, and step-wise forward. If the model selection procedure revealed different

final models, the model with the highest adjusted R^2 was selected. To correct for multiple testing, we adjusted the p-values for R of the six overall models (one correction per age point) using Hochberg's improved Bonferroni correction (Shaffer, 1995). Adjusted p-values are reported here. A null hypothesis was rejected at an α-level of 0.05.

For the regressions with infant measures at 1 month and maternal education as predictors, and with maternal speech measures at 1 month as dependent variables, R of the overall model did not significantly differ from zero for any of the six regression models, all adjusted ps > 0.05. There was no significant relation of any maternal speech measure with any infant behavior or maternal educational level during mother–infant interaction when infants were 1 month old.

For the regressions with infant measures at 3 months and maternal education as predictors, and with maternal speech measures at 3 months as dependent variables, R of the overall model was significantly different from zero for the regression models with the following dependent measures: MLU, $F(4, 55) = 3.61$, $p < 0.05$, adjusted $R^2 = 0.15$, token rate, $F(1, 58) = 10.74$, $p < 0.05$, adjusted $R^2 = 0.14$, and one-word-utterances, $F(3, 56) = 4.43$, $p < 0.05$, adjusted $R^2 = 0.15$. For the regression models with utterance rate, VOCD and interrogatives as dependent variables, R of the overall model did not significantly differ from zero, adjusted ps > 0.05. Table 2 displays the R^2 of the overall models and the unstandardized regression coefficients (B), the standard errors of B, the standardized regression coefficients (β), and the squared part correlations (sr^2) of the predictor variables for the regressions with MLU, token rate, and one-word-utterances as dependent variables, respectively. In multiple regression, the squared part correlation (sr^2) is the proportion of the variance in the dependent variable accounted for by adding the given independent variable to those entered earlier in the multiple regression formula. As shown in Table 2, during mother–infant interaction when infants were 3 months old, infant positive vocalizing was significantly related to token rate, MLU, and one-word-utterances, regardless of maternal education. With more infant

Table 2
Relation of infant behavior to maternal speech at 3 months

Independent variable	B	S.E. of B	β	sr^2
MLU (DV), $R^2 = 0.21$				
Maternal education	0.52*	0.22	3.00	0.08
Infant gazing	0.01	<0.01	0.15	0.02
Infant smiling	0.01	0.01	0.16	0.02
Infant positive vocalizing	−0.03*	0.01	−0.29	0.08
Token rate (DV), $R^2 = 0.16$				
Infant positive vocalizing	−1.10**	0.33	−0.40	0.16
One-word-utterances % (DV), $R^2 = 0.19$				
Maternal education	−6.03	3.03	−0.24	0.06
Infant smiling	−0.28	0.15	−0.23	0.05
Infant positive vocalizing	0.44*	0.18	0.31	0.09

Multiple regressions with maternal speech at 3 months as dependent variable, and infant behaviors in percent of time at 3 months and maternal education (0–1 dummy coded) as independent variables. For each dependent measure the model with the highest adjusted R^2 was selected. In this table displays only the regressions with R of the overall model significantly different from zero with adjusted p-values to correct for multiple testing. MLU = mean length of utterances. DV = dependent variable.

* $p < 0.05$.

** $p < 0.01$.

positive vocalizing, mothers produced fewer words, shorter utterances, and more one-word-utterances. The unique contribution of infant positive vocalizing to the total variance of maternal speech at 3 months, expressed by sr^2, was between 8 and 16%. Also, maternal education correlated positively with MLU and negatively with one-word-utterances, indicating that utterances of mothers with higher education were longer than utterances of mothers without higher education, and that mothers with higher education produced less one-word-utterances than mothers without higher education[3].

3.2.2. Stable individual differences in maternal speech styles

To assess stability of individual differences in mothers' speech to their infants at 1 and 3 months, we performed standard multiple regressions, one for each maternal measure, between maternal speech at 3 months as dependent variable, and maternal speech at 1 month and maternal education as independent variables. To correct for multiple testing, we adjusted the *p*-values for *R* of the six overall models using Hochberg's improved Bonferroni correction (Shaffer, 1995). Adjusted *p*-values are reported here. A null hypothesis was rejected at an α-level of 0.05.

For all regressions, *R* of the overall model was significantly different from zero: MLU, $F(2, 57) = 20.82$, $p < 0.001$, adjusted $R^2 = 0.42$, utterance rate, $F(2, 57) = 8.66$, $p < 0.01$, adjusted $R^2 = 0.30$, token rate, $F(2, 57) = 11.79$, $p < 0.001$, adjusted $R^2 = 0.27$, VOCD, $F(2, 57) = 15.80$, $p < 0.001$, adjusted $R^2 = 0.36$, interrogatives, $F(2, 57) = 7.15$, $p < 0.05$, adjusted $R^2 = 0.12$, and one-word-utterances, $F(2, 57) = 31.75$, $p < 0.001$, adjusted $R^2 = 0.44$. Table 3 displays the R^2 of the overall models and the unstandardized regression coefficients (*B*), the standard errors of *B*, the standardized regression coefficients (β), and the squared part correlations (sr^2) of the predictor variables for all six regressions, respectively. Maternal speech at 3 months was positively related to maternal speech at 1 month for all six measures, independent of maternal education. The unique contribution of maternal speech at 1 month to the total variance of maternal speech at 3 months, expressed by sr^2, was between 13 and 39%. These findings suggest that individual differences in amount and diversity of maternal speech were stable between 1 and 3 months.

4. Discussion

The goal of the present study was to investigate maternal speech at 1 and 3 months in relation to an important transition in infant development occurring around the second month of life. We analyzed infant behavior and maternal speech in face-to-face interaction during two consecutive visits when infants were 1 and 3 months old.

Results showed that infants increased amount of gazing and length of gaze bout to the mother between 1 and 3 months, indicating an increase in infant visual attention to their mothers. Infants also increased

[3] On the suggestion of one reviewer, we have performed further multiple regressions to assess the associations between maternal speech at visit 1 and infant behavior at visit 2, and between infant behavior at visit 1 and maternal speech at visit 2. The same strategy of analyses and correction for multiple testing was used. For the regressions with maternal speech measures at 1 month as predictors, and with infant measures at 3 months as dependent variables, *R* of the overall model was not significantly different from zero for any of the regression models, all adjusted ps > 0.05. For the regressions with infant measures at 1 month and maternal education as predictors, and with maternal speech measures at 3 months as dependent variables, *R* of the overall model was not significantly different from zero for any of the regression models, all adjusted ps > 0.05. These null results further strengthen our finding that maternal speech related systematically to infant positive vocalizing at 3 months.

Table 3
Stable individual differences in mothers' speech to their infants at 1 and 3 months, independent of maternal education

DV (v2)	IV	R^2	B	S.E. of B	β	sr^2
MLU		0.44				
	MLU v1		0.46**	0.08	0.61	0.35
	Maternal education		0.26	0.18	0.15	0.02
Utterance rate		0.33				
	Utterance rate v1		0.60**	0.12	0.56	0.31
	Maternal education		−1.28	1.23	−0.11	0.01
Token rate		0.38				
	Token rate v1		0.45**	0.10	0.53	0.31
	Maternal education		2.48	5.45	0.05	<0.01
VOCD		0.30				
	VOCD v1		0.56**	0.11	0.59	0.28
	Maternal education		3.01	5.78	0.06	<0.01
Interrogatives		0.15				
	Interrogatives v1		0.38*	0.11	0.37	0.37
	Maternal education		−4.95	3.52	−0.17	−0.17
One-word-utterances		0.46				
	One-word-utterances v1		0.58**	0.09	0.65	0.63
	Maternal education		−1.81	2.55	−0.07	−0.07

For each maternal speech measure a standard multiple regression was conducted between maternal speech at 3 months (v2 = visit 2) as dependent variable (DV), and maternal speech at 1 month (v1 = visit 1) and maternal education (0–1 dummy coded) entered as independent variables (IV). MLU = mean length of utterances; VOCD = vocabulary diversity.
* $p < 0.01$.
** $p < 0.001$.

smiling and positive vocalizing between 1 and 3 months suggesting an increase in infant social responsiveness over visits. Similarly, whereas only about half of the infants smiled at their mothers during interaction at 1 month, almost all of them smiled at 3 months. These findings are consistent with prior research on changes in infant gazing and attention around the second month (e.g., Kaye & Fogel, 1980; Maurer & Salapatek, 1976), and on the emergence of socially elicited smiling by 1.5 months of age (e.g., Wolff, 1987). Also a trend showing a decrease in negative vocalizing is consistent with an increase in stability of infant state around the second month of life (Wolff, 1987).

Interestingly, the results replicate Kaye and Fogel's (1980) findings for 1.5- and 3-month-olds only in part. Kaye and Fogel reported also an increase in infant responsiveness, indicated, e.g., by smiling and vocalizing, but in contrast with our findings, a decrease in infant attention to their mother. These discrepancies could be due to differences in sample size, methodology, or cultural differences. In their study, dyads were tested at their homes, making it likely that other objects could have attracted infants' attention. Also, sessions in Kaye and Fogel's study were longer than in the current study. Finally, the Kaye and Fogel sample was predominantly American, while in the current study dyads were German. Overall, the findings reported here suggest a transition in infant development between 1 and 3 months that leads to visible changes in infant social behavior in dyadic interactions.

It is likely that changes in maternal speech between visits reflect these changes in infant behavior. Confirming this idea, maternal speech showed an increase in amount and diversity of maternal linguistic input between 1 and 3 months regardless of individual differences related to social class or speech style. At 1 month, mothers' use of relatively little and simple speech likely reflected their main concern of establishing a contact, i.e., eliciting infant attention and prevent fussiness. At 3 months, maternal utterances were longer and an increase in lexical diversity indicated a use of more contentful speech. These changes might reflect a shift in maternal focus from trying to establish dyadic contact to elaborating on it, in relation to their 3-month-olds' ability to engage more easily and for longer bouts in face-to-face interaction.

As infants were more active participants in interaction at 3 months, differences in maternal speech were likely due to the infant's changing status in the relationship (Kaye, 1980). According to Vedeler (1987), attribution of intentionality is triggered by directionality of behavior. Attentive, long and clear gazes as well as smiles in response to maternal gaze have a more directional quality than glassy, hazy eyes that easily drift in focus. Hence, although parents in Western middle-class cultures treat infants as interlocutors from the beginning (e.g., Kaye, 1982), it is likely that with an increase in directionality of infant behavior, and with a clear focus on the interacting parent, mothers perceived their infants as overall more communicative and hence talked more.

Besides overall differences in maternal speech at 1 compared to 3 months, maternal speech might also reflect this different quality of interaction at 3 months, when mutual influences between maternal and infant behavior in dyadic interaction have increased compared to interaction at 1 month (e.g., Lavelli & Fogel, 2005). Confirming this idea, three maternal measures, MLU, token rate and one-word-utterances, were related to infant positive vocalizing at 3 months, whereas no significant relations between infant and maternal measures were found at 1 month. Consistent with research on early mother–infant vocal coordination (e.g., Jaffe et al., 2001; Lavelli & Fogel, 2005), these findings suggest that at 3 months, when infants were overall more responsive and their behavior likely more predictable, infant positive vocalizing was systematically related to maternal speech, and mothers seemed to closely monitor infant positive vocalizing as index of infant social engagement.

As the literature on features of ID speech suggests, a decrease in MLU, number of words, and an increase in proportion of one-word-utterances used could be interpreted as an increase in ID speech features in maternal speech, i.e., in simplicity and likely also in rhythm. According to Murray and Trevarthen (1986), ID speech "arises as a function of the quality of interpersonal engagement that takes place" (p. 26). Consequently, the finding that simplicity and likely rhythm of maternal speech was related to positive vocalizing at 3 months could be interpreted as an increase in ID speech features in maternal speech that is related to infant vocal participation in the interaction. Also, and consistent with an underlying communicative function of ID speech (Brown, 1977), the finding that maternal verbal input decreased with an increase in infant positive vocalizing can be interpreted as mothers ceding the turn to the infant in order to maintain a conversational model (Snow, 1977). Similarly, the positive relation between maternal one-word-utterances and infant positive vocalizing suggest that at 3 months, when infants are more vocally participating than at 1 month, mothers make more use of phatics such as *hm* or *ja* (*yes*), to acknowledge infant positive vocalizations as a turn in conversation (Kaye, 1980,1982). It is interesting to note that over one third of one-word-utterances were uttered with a rising intonation contour, i.e., most likely to encourage infant turn taking (Papousek et al., 1991).

The relations found at 3 months between infant vocalizing and maternal speech are consistent with prior findings on the effectiveness of infant non-distress vocalizing on maternal responsiveness (e.g.,

Bornstein et al., 1992), and on changes in infant vocal development, e.g., on-set of cooing by 1.5 months of age (Stark, 1978). Interestingly, this new and more speech-like quality of infant vocalizing is perceived by adults as more communicative and likely influences their vocal responsiveness (Beaumont & Bloom, 1993; Masataka & Bloom, 1994). Although Hsu and Fogel (2003) found that only the occurrence but not the quality of infant non-distress vocalizing regulated maternal verbal response in interaction, it is likely that an overall increase in infant social behavior and the emergence of social smiling and cooing results in a general perception of the infant as having become a more able interlocutor. This would explain the apparently systematic relation between infant positive vocalizing and maternal linguistic input at 3 months.

Alternatively, mothers could have increased ID speech features not in response but in order to elicit infant vocal participation, as ID speech has been shown to tune into infant discriminatory abilities and preferences (e.g., Cooper & Aslin, 1990; Fernald, 1993; see also Bloom, Russell, & Wassenberg, 1987). Though influences were likely bidirectional (e.g., Lavelli & Fogel, 2005), directionality of effects between infant behavior and maternal speech variables cannot be established given the correlational nature of the data. Future research is needed to address this question, for example, by experimentally manipulating maternal linguistic input to infants in dyadic interaction similar to the work of Bloom et al. (1987). However, it is interesting to note that despite mutual influences between various infant and maternal behaviors such as gazing, smiling and vocal behavior (e.g., Lavelli & Fogel, 2005), in the current study, maternal linguistic input only related to infant positive vocalizing, and relations were found only between maternal and infant measures at 3 months but not at 1 month or across visits. These findings suggest that maternal attention to infant positive vocalizing at 3 months was reflected in maternal speech.

Admittedly, maternal speech has been sampled from only 3 min of interaction. However, consistent with findings on stable individual differences in maternal speech styles (e.g., Kaye, 1980), in the current study individual differences in amount and diversity of maternal speech were stable over time. These results further support our findings on age-related changes in maternal speech, as they suggest that both relatively quiet mothers and more chatty ones, increased amount and diversity of speech between 1 and 3 months. Also, speech of mothers with higher education was characterized by a richer vocabulary, longer utterances and fewer one-word-utterances than speech of mothers without higher education. Maternal educational level is commonly included among the indices of social class and has shown to influence maternal speech to children (e.g., Tulkin & Kagan, 1972). Since our findings are consistent with prior research, we believe that the relatively short recording of maternal speech still reliably captured the phenomena.

In summary, the findings of the current study point to a transition in infant social behavior at around the second month post birth and suggest that mothers attuned their speech to the infants' increased ability to participate and reciprocate in dyadic interaction. As infants were more able to participate in interaction with their mothers and showed more communicative behavior at 3 compared to 1 month, maternal speech to infants increased between these times in both amount and complexity. In addition, besides an overall increase in amount and diversity of speech, maternal speech was also systematically related to infant positive vocalizing at 3 months, probably reflecting mothers' perception of infants as more communicative and, hence, their attempt to engage them in vocal conversation by ceding the turn to the infant and by using phatics to acknowledge in infant's vocal turn. These findings extend previous literature on maternal attunement to infant communicative ability and point to the importance of vocal interchange in Western middle-class cultures.

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Appendix A. Transcript of the first 50 s of a dyad's interaction at 1 month

*MUT:ja?	yes?
*MUT:was denn?	*what is it?*
*MUT:guck mal, wo wir hier sind.	*look, where we are here.*
*MUT:ja, schatzel.	*yes, dear.*
*MUT:bist du muede?	*are you tired?*
*MUT:bist du ganz muede, ja?	*are you very tired, yes?*
*MUT:guck dich mal um.	*have a look around.*
%com: baby quengelt.	*baby fusses.*
*MUT:nicht, wah@o aber +/.	*don't, wah@o but +/.*
%com: baby quengelt und unterbricht dadurch mutter.	*baby fusses, interrupting mother.*
*MUT:psch@o.	*psss@o.*
%com: baby faengt an zu weinen.	*baby starts crying.*
*MUT:nein, schatzi.	*no, dear.*
*MUT:das wollen wir doch gar nicht.	*we really don't want this.*
*MUT:guck mal, wo wir hier sind.	*look, where we are here.*
*MUT:ja.	*yes.*
*MUT:lach mal.	*smile.*
*MUT:lach mal die mama an.	*give mommy a smile.*

*MUT:ja lach mal die mama an.	*yes give mommy a smile.*
%com: baby quengelt.	*baby fusses.*
*MUT:ja.	*yes.*
*MUT:oh@o.	*oh@o.*
*MUT:ganz muede.	*so tired.*
*MUT:ganz muede schatz.	*so tired dear.*
*MUT:lach mal die mama an.	*give mommy a smile.*
*MUT:lach sie mal an, ei@o.	*give her a smile, ei@o.*
*MUT:fein.	*fine.*
*MUT:ja, das ist doch schoen.	*yes, that is nice.*
*MUT:hm@o?	*hm@o?*
*MUT:fein.	*fine.*
%com: baby macht geraeusche waehrend mutter das sagt.	*baby is vocalizing while mom is talking (previous line).*
*MUT:ja.	*yes.*
*MUT:ja?	*yes?*
*MUT:lach sie mal an.	*give her a smile.*
*MUT:ja?	*yes?*
*MUT:mach mal dein muendchen auf.	*open your little mouth.*
*MUT:oh@o, bist du ganz muede?	*oh@o, are you so tired?*
*MUT:ganz muede?	*so tired?*

*MUT: speaker tier of the mother containing all transcribed meaningful vocalizations. %com: dependent tier (i.e., referring to the preceding speaker tier) containing a comment on the preceding speaker tier such as infant vocalizations and other activity that qualify or are referred to in the precedent speaker tier. %par: dependent tier containing maternal paralinguistic information, e.g., laughing, kissing, tongue clicking, and singing. −@o: marker used for fillers and sounds such as *hm*, *oioioi*, and *oh*. +/.: marker for maternal utterances that are incomplete because interrupted by infant vocalizing.

Appendix B. Transcript of the first 50 s of the same dyad's interaction at 3 months

*MUT:hallo?	*hello?*
%com: baby macht geraeusche.	*baby vocalizes.*
*MUT:freust du dich fein?	*are you happy?*
*MUT:ja?	*yes?*
*MUT:wo sind wir denn hier, schau mal, wo wir hier sind.	*where are we here, look, where we are here.*
*MUT:freust du dich, dass wir hier sind?	*are you happy to be here?*
*MUT:sag mal ah@o.	*say ah@o.*
%com: baby macht geraeusch.	*baby vocalizes.*
*MUT:ja?	*yes?*
*MUT:sag mal ah@o.	*say ah@o.*
%com: baby macht geraeusch.	*baby vocalizes.*
*MUT:das kannst du doch schon.	*you know how to do it.*
*MUT:sag mal ah@o.	*say ah@o.*
*MUT:hm@o?	*hm@o?*
*MUT:willst du nicht mit der mama sprechen jetzt?	*don't you want to talk with mommy now?*
*MUT:erzaehl mal uns was.	*tell us something.*
*MUT:ja?	*yes?*
*MUT:erzaehl uns mal was.	*tell us something.*
*MUT:hm@o, schatzel.	*hm@o, dear.*
*MUT:machst du mal, ja, machst du mal ah@o.	*can you do, yes, can you do ah@o.*
*MUT:das ist lustig, hm@o.	*that's funny, hm@o.*

*MUT:das findst du ganz lustig.	
	you think that's really funny.
*MUT:ja, das findst du ganz lustig, wenn die mama ah@o macht.	
	yes, you think that's really funny, when mommy does ah@o.
%com: baby macht geraeusche.	
	baby vocalizes.
%par: mutter lacht.	
	mother laughs.

*MUT: speaker tier of the mother containing all transcribed meaningful vocalizations. %com: dependent tier (i.e., referring to the preceding speaker tier) containing a comment on the preceding speaker tier such as infant vocalizations and other activity that qualify or are referred to in the precedent speaker tier. %par: dependent tier containing maternal paralinguistic information, e.g., laughing, kissing, tongue clicking, and singing. −@o: marker used for fillers and sounds such as *hm*, *oioioi*, and *oh*. +/.: marker for maternal utterances that are incomplete because interrupted by infant vocalizing.

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