
THE INFLUENCE OF PREMATURITY, MATERNAL ANXIETY, AND INFANTS' NEUROBIOLOGICAL RISK ON MOTHER–INFANT INTERACTIONS

GESINE SCHMÜCKER

University of Ulm

KARL-HEINZ BRISCH

Ludwig-Maximilians-University, Munich

**BRIGITTE KÖHNTOP, SUSANNE BETZLER, MARGRET ÖSTERLE,
FRANK POHLANDT, AND DAN POKORNY**

University of Ulm

MANFRED LAUCHT

Central Institute of Mental Health, Mannheim

HORST KÄCHELE AND ANNA BUCHHEIM

University of Ulm

ABSTRACT: In this study, we investigated how the birth of a very low birth weight preterm (VLBW) infant influences the mother–infant interaction at 3 months. We also focused on the impact of the infant's neurobiological risk and maternal anxiety, and their interaction. The comparison of the VLBW preterm sample ($n = 79$) with an external full-term sample ($n = 35$) showed mother–infant interactions of the families with the preterm infant to be more vocally responsive during the interaction, but less facially responsive during the interaction. Additionally, higher levels of maternal anxiety were associated with preterm infants being less facially responsive in interaction with their mother. While neurobiological risk of the infant played a part in this association, with higher risk infants also being less facially responsive,

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the relationship with maternal anxiety and the mother–child interaction was stronger. How these findings may influence therapeutic interventions is discussed.

RESUMEN: En este estudio investigamos cómo puede el nacimiento de un infante prematuro con un muy bajo peso (VLBW) influir en la interacción entre la madre y el infante a los 3 meses del nacimiento. También nos enfocamos en el impacto del riesgo neurobiológico del infante y la ansiedad materna, así como en la interacción entre estos factores. La comparación entre los infantes prematuros del grupo muestra de VLBW (n=79) y un grupo muestra externo de infantes nacidos a los nueve meses (n=35) demostró que las interacciones madre-infante en las familias con los infantes prematuros eran vocalmente más sensibles, pero facialmente menos sensibles durante la interacción misma. Adicionalmente, se asociaron los altos niveles de ansiedad materna con el hecho de que los infantes prematuros eran facialmente menos sensibles en las interacciones con sus madres. Mientras que el riesgo neurobiológico del infante jugó un papel en toda esta asociación, y con los infantes de alto riesgo siendo también menos sensibles facialmente, la relación entre la ansiedad materna y la interacción madre-infante fue más fuerte. Se discutirá cómo estos resultados pudieran influir las intervenciones terapéuticas.

RÉSUMÉ: Dans cette étude nous avons enquêté sur la manière dont la naissance d'un bébé né avant terme de poids extrêmement faible (abrégé VLBW en anglais) influence l'interaction mère-bébé à l'âge de trois mois. Nous avons aussi mis l'accent sur l'impact du risque neurobiologique du bébé et de l'anxiété maternelle, et leur interaction. La comparaison d'un échantillon de bébés VLBW (n=79) avec un échantillon de bébés nés à terme (n=35) a démontré que les interactions mère-bébé des familles avec le bébé né avant terme étaient plus réceptives vocalement durant l'interaction, mais moins réceptives facialement durant l'interaction. De plus, de plus hauts niveaux d'anxiété maternelle étaient liés au fait que les bébés nés avant terme étaient moins réceptifs facialement avec leur mère. Bien que le risque neurobiologique du bébé jouaient un rôle dans cette association, les bébés le plus à risque étant aussi les moins facialement réceptifs, le lien avec l'anxiété maternelle et l'interaction mère-enfant était plus fort. Nous discutons la manière dont ces résultats peuvent influencer les interventions thérapeutiques.

ZUSAMMENFASSUNG: In dieser Studie untersuchten wir inwieweit die Geburt eines sehr kleinen Frühgeborenen (VLBW) die Mutter-Kind Interaktion im Alter von drei Monaten beeinflusst. Wir beachteten auch die Bedeutung des neurobiologischen Risikos des Kleinkinds und die mütterliche Angst und deren Interaktion. Der Vergleich der VLBW-Stichprobe (n=79) mit einer auswärtigen, reifgeborenen Stichprobe (n=35) zeigte, dass in der Mutter-Kind Interaktionen der Familien mit Frühgeborenen mehr verbaler Austausch stattfand, aber die Interaktion weniger mimische Stimmigkeit zeigte. Zusätzlich war höhere mütterliche Ängstlichkeit mit geringem mimischem Austausch auf Seiten des Frühgeborenen assoziiert. Wohingegen das neurobiologische Risiko der Kleinkinder einen Anteil bei dieser Assoziation hatte – wodurch Hochrisikokinder weniger mimisch stimmig waren – war die Assoziation mit mütterlicher Ängstlichkeit und der Mutter-Kind Interaktion stärker. Wie diese Ergebnisse therapeutische Interventionen beeinflussen könnten, wird ebenfalls besprochen.

抄録：この研究では、われわれは極低出生体重 (VLBW) 早期産児の誕生が、どのように 3 カ月時の母–乳児相互交流に影響を与えるかを研究した。われわれはまた、乳児の神経生物学的リスクと母親の不安、そして両者の相互交流に焦点付けた。VLBW 早期産児 (n=79) を外部の満期産児 (n=35) と比較すると、早期産児のいる家族の母–乳児相互交流は、相互交流のあいだの言語的な反応がより多く、相互交流のあいだの表情による反応がより少ないことが示された。さらに、高い水準の母親の不安は、母親との相互交流のあいだに早期産児が表情による反応がより少ないことと関連していた。乳児の神経生物学的リスクがこの関連の一翼を担っている、すなわちよりリスクの高い乳児はまた、表情による反応がより少ないのではあるが、母親の不安と母–乳児相互交流の関係の方がより強かった。これらの所見が治療的介入に与える影響について議論されるだろう。

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INTRODUCTION

Great advances in perinatal medicine have led to considerable decrease in the mortality rate of preterm infants in the last decade; however, the emotional burden on parents is still considerable (Cobiella, Mabe, & Forehand, 1990). The premature birth of a very low birth weight (VLBW) infant (weighing less than 1,500 g) is considered to be a time of crisis for parents, especially as many preterm births are unexpected. Parents' anticipated joy is often replaced by a feeling of impending catastrophe. The stresses experienced during the normal transition to parenthood are compounded by a situation in which parents have to relinquish control over their baby. Normal routine is disturbed as the hospital dictates the care of the infant, and in addition, uncertainty about their infant's survival (i.e., fear of loss) may lead to anxiety and difficulties in forming a relationship. As VLBW preterm infants spend at least their first days in an incubator, spontaneous caressing is limited. If mothers want close bodily contact, such as having their infant in their arms or on their chest, medical staff is needed to assist in arranging tubes and cables which connect the infant to medical apparatus. Thus, the formation of the early relationship between the mother and her infant takes place in a highly technical environment, which may represent an obstacle to this formation as intimacy can only be created with great effort (Perehudoff, 1990).

In addition to the stressful environment of the neonatal intensive care unit (NICU), preterm infants' neurological immaturity makes it difficult for mothers to interact with their infants. Preterm infants may have suffered complications such as hemorrhages, which are known to be a risk for perceptual and sensory deficits as well as disorders of coordination (Landry, Leslie, Fletcher, & Francis, 1985).

Early studies have shown preterm infants in the first year of life to be less rewarding interactive partners when compared to full-term infants. They show more negative affect (Brachfeld, Goldberg, & Sloman, 1980), less positive affect (Garner & Landry, 1992), and are more passive and less socially responsive (Malatesta, Grigoryev, Lamb, Albin, & Culver, 1986). Als (1983) described preterm infants as being difficult to bring to an attentive state, and once in this attentive state, they are more likely to become overaroused. Pauli-Pott (1991) also found preterm infants to be less responsive, more irritable, and less able to regulate states of arousal, showing more negative affect and often avoiding eye contact.

In addition, most mothers of preterm infants when compared to mothers of full-term infants have been found to be more passive and less loving (Barnard, Bee, & Hammond, 1984), and show less positive facial expression (Cnic, Ragozin, Greenberg, Robinson, & Basham, 1983); however, there are other studies which show that mothers are able to compensate for these difficult circumstances. During interaction, mothers of preterm infants have been shown to be more gentle (Crawford, 1982), seek more physical contact (Malatesta et al., 1986), and are more active (Cnic et al., 1983) than mothers of full-term infants.

Differences seen in the interaction between full-term and preterm mothers and infants are largely attributed to the neurological immaturity of the preterm infant (Greene, Fox, & Lewis, 1983). More specifically, a follow-up study of 8-year-olds (Peterson et al., 2000) showed VLBW children have smaller regional cortical volumes when compared to matched controls. Furthermore, Peterson et al.'s study showed that measures of full-scale, verbal, and performance IQ scores had a direct association between volumes of sensorimotor and midtemporal cortices.

However, maternal factors also may account for observed differences in mother–baby interactions: Mothers were found to react to a premature birth with anxiety, grief, feelings of

loss and separation, helplessness, anguish, depression, stress, and symptoms of posttraumatic stress disorder (Gennaro, York, & Brooten, 1990; Holditch-Davis, Bartlett, Blickman, & Miles, 2003; Locke et al., 1997; Singer et al., 1999). A study by Poehlmann and Fiese (2001) indicated that the more depressive symptoms a mother of a preterm infant had (even at the subclinical level), the more likely the infant was to be insecurely attached. In full-term infants, no such relationship was found. Therefore, both preterm infants (at neurobiological risk) and mothers (with emotional distress) contributed to the quality of the interaction.

Anxiety in particular was associated with the maternal experience of a premature birth and was dependent in part on the neurobiological risk status of the preterm infant (Blumberg, 1980; Silcock, 1984).

Maternal anxiety manifests in the way mothers interact with their children (Whaley, Pinto, & Sigman, 1999). Heightened maternal anxiety contributed to mothers showing less warmth and positive emotion while demonstrating catastrophic and negative thinking in excess when compared to mothers of a control sample. These interaction characteristics can contribute considerably to the child's own development of anxiety, and therefore are relevant to the trans-generational transmission of psychopathology. On the other hand, the degree of responsiveness of the mother is a central characteristic of sensitive mother–infant interaction. Mothers who respond promptly and sensitively to the infants' affective signals strengthen the mother–infant bond (Tronick & Weinberg, 1997). Responsive mothers have more vocal infants with higher levels of sensorimotor functioning (Beckwith & Rodning, 1997).

Numerous studies indicate that maternal well-being influences the quality of mother–infant interaction (reviewed by Cummings & Davies, 1994), and in particular, the importance attributed to the *quality* of emotional exchange during an interaction predicts later social and cognitive development (Esser et al., 1996; De Wolff & van IJzendoorn, 1997; Miller, Cowan, Cowan, Hetherington, & Clingempeel, 1993; Murray, Kempton, Woolgar, & Hooper, 1993).

Further research is needed to discover to what extent maternal anxiety *in conjunction with* the neurobiological risk of the infant influences the mother–infant interaction in preterm samples.

This article focuses on the mother–infant interaction at 3 months' corrected age and asks to what extent interactions differ between the preterm and the full-term comparison sample. In the preterm sample only, we investigated how the degree of neurobiological risk and maternal anxiety was demonstrated in the mother–infant interactions.

Hypotheses

The following three hypotheses were investigated:

1. The interactions of the preterm infants and their mothers (responsiveness and sensitivity) will differ from the interactions of a comparison sample of full-term infants and their mothers. The direction of the differences in specific variables will be examined in exploratory fashion, as the literature reports contradictory findings.
2. In the preterm sample, the infants' neurobiological risk will be associated with the mother–infant interaction. Particularly, we expect to find that (a) the higher the neurobiological risk of the infants, the less responsive and emotionally expressive they will be during interactions with their mothers; and b) the higher the neurobiological risks of the infants, the less emotionally expressive and sensitive their mothers will be.
3. In the preterm sample, maternal anxiety is associated with the mother–child interaction. The more anxious the mothers are, the less favorable the mother–child interactions will be. Interactions of anxious mothers and their infants will be less positive and more negative than interactions of mothers with less anxiety.

METHOD

Study

A longitudinal prospective study was conducted focusing on the emotional, behavioral, and cognitive development of VLBW preterm infants in the first 2 years of life (Brisch et al., 1996). The study had an intervention component, with 88 families taking part in a prospective randomized intervention study. Forty-four families were in the intervention group (preterm intervention), and 44 families were in the control group (preterm control). The psychotherapeutic intervention was aimed at facilitating the process of early parent–child attachment, which was assessed at 14 months' corrected age with the Strange Situation Test (Ainsworth, Blehar, Waters, & Wall, 1978). The psychotherapeutic intervention was *not* tailored to alter the mother–child interaction as assessed at 3 months' corrected age. The intervention was comprised of five sessions each of attachment-oriented individual psychotherapy and supportive group psychotherapy (offered in the first months when the preterm was an inpatient), a home visit after the infant was discharged from the hospital, and a sensitivity training conducted *after* the recording of mother–child interaction presented in this article. Once the intervention study was completed, an additional 35 families (preterm later recruits) were recruited from the same hospital following the same experimental procedure as the control group of the intervention study to fulfill grant-awarding-bodies' requirements of an adequate sample size.

The Ulm Hospital study had been originally planned as a randomized design to study the influence of an intervention program for parents of preterm infants. One part of the intervention program was a videotaped mother–infant interaction, which served as a tool to educate the parents and increase their capacity for sensitivity. A matched full-term control group was not recruited from the same Ulm Hospital, as the main interest of our study lay in assessing the influence of the psychotherapeutic intervention on the family's emotional well-being, and therefore resources were focused on the preterm sample. Nevertheless, the experimental setting of mother–infant interactions as seen in diaper changes and in playing was equivalent with the procedure used in the parallel study in Mannheim. Data of 35 full-term infants and their mothers from a study conducted in Mannheim were used for baseline comparison. This full-term sample had neither biological nor psychosocial risk and thus constituted a control sample against which the preterm infants and their mothers could be compared; however, we were aware of the following five problems connected to the comparison with this external control group: (a) The two study groups were from different South-German centers; (b) in the Mannheim study, parents with social risk were excluded; (c) in Mannheim, only firstborn infants were investigated; (d) in Ulm, we worked with three preterm subgroups (intervention, no intervention, later recruited); and (e) some measurements were not administered across both samples. In the control sample, there was per definition no neurobiological risk, and maternal anxiety, while assumed to be low, was not recorded.

In comparing the Ulm and Mannheim samples, we controlled for the influences of these factors by: (a) limiting our preterm sample to families with no psychosocial risk, (b) statistically controlling for the factor “first-/later born infant,” and (c) controlling for the factor of three subgroups. Finally, some hypotheses could be formulated only for the Ulm study group.

Preterm Sample

Families were recruited for the study in the first days after the birth of their preterm infant (<1,500 g) at Ulm University Hospital. All mothers who had given birth to a preterm infant weighing less than 1,500 g and who fulfilled the following criteria were asked to participate

in the study: They had good spoken German, their child survived the first 3 days, they did not take part in other psychotherapeutic intervention studies conducted in the hospital, and their child was not transferred to another hospital in the first week. All mothers fulfilling these criteria were approached by one of the researchers while on the maternity ward. Of a possible sample of 374 mothers (November 1994–July 1998), 94 (25%) were excluded for one of the reasons mentioned earlier. The remaining 280 mothers were approached and asked to participate in the study. The aim of the study was explained by one of the research psychologists, and both parents were asked to participate. After 123 (44%) families agreed to take part in the study, mothers and fathers were asked to complete a series of questionnaires. Only those measures relevant to this article will be mentioned here.

Of the 123 families with VLBW preterm infants who took part in the study, there were data available on 102 mother–infant pairs; specifically, the mother–infant interaction at 3 months' corrected age. The data of 21 families were not included because: Four infants died before the 3 months' assessment; 8 infants were inpatients at the time of the assessment; in one family, the parents could not be separated from one another for dyadic interactions with their infant; 7 families decided not to continue in the study; and in one family, only the father took part in the study, and hence, there was no mother–infant interaction for this family.

There was one significant difference between the families who participated in the study and those who dropped out after initially having agreed to participate. The “dropout” sample ($n = 7$) had significantly more multiparous births than the sample group ($n = 102$) who continued to participate, Fisher exact test $p = .007$.

To control for the confounding variables of psychosocial risk and birth order in the preterm sample, but keeping the sample of preterm infants as large as possible, the following decisions were made: Only those families were included in the analyses who did not fulfill any of the criteria of psychosocial risk as defined by the Mannheim sample, which used Rutter and Quinton's (1977) Family Adversity Index and comprised of 11 different risk factors (for more detail, refer to Laucht, Esser, & Schmidt, 1997). Hence, 23 families were excluded, leaving a sample of 79 preterm infants and their families with no psychosocial risk. To ensure birth order would not confound the comparison between the full-term and the preterm sample, multivariate analyses were conducted testing for the effect of birth order on the mother–infant interaction. Results showed no significant difference in the way firstborn and later born mother–infant pairs interacted, $F(17, 61) = .814$, n.s.

In addition, the three subsamples of preterm infants were compared (preterm intervention, preterm control, and preterm later recruits). Using multivariate analyses, no significant differences were found between the three subsamples in the mother–child interaction, the anxiety mothers experienced in the first months after the birth of their infant, gestational age of the infant, birth weight, neurobiological risk score of the infant, age of the mother, and life events of the mother, $F(76, 50) = 1.1$, n.s. Thus, the three subsamples were pooled, resulting in sample of 79 families of preterm infants. Results suggested that contrary to our expectations, no difference in the quality of attachment of the preterm infants to their mother was found between the intervention and the control group (Brisch, Bechinger, Betzler, & Heinemann, 2003). Possible reasons for the lack of the intervention effect will be expanded upon in the discussion.

The clinical characteristics of the preterm sample are shown in Table 1. Most of the infants (84%) were delivered by Cesarean section, 12 infants were on a ventilator for more than 28 days, 3 infants had an intraventricular hemorrhage, and 3 infants developed periventricular leukomalacia. Eighteen infants were small for gestational age (assessed according to Voigt, Schneider, & Jahrig, 1996). Thirty-six were boys, and 43 were girls; 62% of the infants were firstborns.

Twenty-two percent of the mothers in this sample were multiparous. From the multiparous

TABLE 1. *Clinical Data of Preterm Sample*

	M	SD	Range
Birth weight (g)	938.3	288.4	450–1490
Gestational age (week)	27.5	2.7	23–35
Inpatient (days)	82.4	37.9	13–165
On ventilator (days)	12.9	18.7	0–83
NBRS score	3.6	3.5	0–17
Maternal age (years)	31.1	4.1	23–42

n = 79. NBRS = Nursery Neurobiologic Risk Score.

families, only 1 infant (firstborn) was included in this sample to maintain statistical independence. A few mothers (7%) had experienced previous premature births, and 23% had miscarried a baby. All parents were married; 72% left school at 16 years of age, and the remaining 28% left later.

Procedure in the preterm sample. An appointment for the initial interview was made with the research psychologist, who was the family's personal contact throughout the study. This first interview provided mothers and fathers with an opportunity to recount their experience of the preterm birth. After this initial interview, parents were asked to fill out a series of questionnaires, including the trait and state forms of the State-Trait Anxiety Inventory (STAI; German version: Laux, Glanzmann, Schaffner, & Spielberger, 1981) and a questionnaire recording sociodemographic data as well as questions about previous stressful life events and previous at-risk pregnancies, which was developed for the purposes of this study.

Four weeks later, the second assessment was conducted. The parents were interviewed again and given the state anxiety form of the STAI. A week before the infants were discharged from hospital, mothers were again asked to provide a third assessment of their state anxiety, and finally, a fourth assessment was gathered at the time of the observation of mother–infant interaction when the infant was 3 months' corrected age. We assumed that at 3 months of age, most of the preterm infants should have been discharged from hospital.

The infant's neurobiological risk was determined by neonatologists during each hospital inpatient stay using the Neurobiological Risk Score (NBRS; Brazy, Eckerman, Oehler, Goldstein, & Rand, 1991; Brazy, Goldstein, Oehler, Gustafson, & Thompson, 1993), and was completed upon the infant's discharge from the hospital.

The mother–infant interaction was filmed at 3 months' corrected age in the research laboratory of the Department of Psychosomatic Medicine and Psychotherapy at the University of Ulm. The comparison sample also was filmed at 3 months. At this age, the expected mother–infant communication is characterized by infants who are able to modulate their social communication on several channels (Stern, 1985): The social smile is evident, vocalization is directed at others and mutual gaze is sought increasingly by the infant.

As parents might have had to travel some distance to the research laboratory, they were welcomed with refreshments and given an opportunity to describe recent developments in the family's life. This "warming-up period" allowed mothers and their infants to feel a little more at ease in the unfamiliar environment before the interaction was filmed. When the infant was awake, alert, and not hungry, the mothers were asked to change their infant's diaper and play with them on a table in the laboratory for 10 min. The infant was positioned lying on his or her back on a changing mat, facing the mother. The mother was free to play with the infant as she wished. The two cameras used to film the interaction (one focusing on the mother, the

other on the infant) were visible to the parents. Use of the split-screen technique (Both mother and infant are visible on the screen simultaneously.) allowed detailed observation of the interaction, which was required for the subsequent coding of the mother–infant interaction. Three colleagues (T.B., E.R., D.M.), who had no additional information about the families, rated the interactions. They achieved good interrater reliability on all 11 scales (median $K \geq .80$) on 15 pilot videotapes. The rating scale (microanalytic coding system of mother–infant interaction, Jörg et al., 1994) focused on both mother’s and infant’s behaviors.

External Full-Term Comparison Sample

The comparison sample ($n = 35$) was recruited as a subsample from a large longitudinal study (Mannheim Study of Risk Children; e.g., Laucht, Esser, & Schmidt, 1994) and consisted of 362 children. This studied the effects of psychosocial and biological risk on children’s development, and thus data were available for our comparative purposes. The sample was classified according to biological and psychosocial risk using predetermined criteria in one of nine categories (for more details, refer to Laucht et al., 1997). The sample of full-term infants was recruited from two obstetric hospitals and six children’s hospitals in the Rhine-Neckar region of Germany. The rate of participation was 64.5% (recruited parents minus refusals), with a slightly lower rate from parents of psychosocially disadvantaged backgrounds.

In the full-term comparison sample, the infants had no pre-, peri-, or neonatal complications and were all firstborns. Their mean gestational age was 39 weeks (range = 38–42, $SD = 1.2$), with an average weight of 3,333 g (range = 2,600–4,130, $SD = 400.3$). Thirteen infants were boys, and 22 were girls. All parents were German speaking, mothers’ mean age was 29 years (range = 23–38), all were in stable partnerships, and all had skilled jobs. Twenty-nine percent of the mothers left school at 16 years of age; the remaining 71% left school at a later age.

Procedure in the external full-term comparison sample. Mothers were asked to come to the video laboratory at the Central Institute of Mental Health when their infants were 3 months of age. As in the preterm sample, mothers and their infants were given an opportunity to become comfortable with the unfamiliar environment by recounting the latest developments in the family’s life. When the infant was awake, alert, and not hungry, the mothers were asked to change their infant’s diaper and play with him or her on a table in the laboratory for 10 min. The infant was positioned lying on his or her back on a changing mat, facing the mother. During the diaper changing and play episode, the parent’s and infant’s interactive behavior was filmed using two cameras.

Measures

Microanalytic coding system of mother–infant interaction. The videotaped interaction was coded by trained observers using the *Microanalytic coding system to rate early mother–child interaction* (Kategoriensystem zur Mikroanalyse der frühen Mutter-Kind-Interaktion; Jörg et al., 1994), which enabled comprehensive ratings of the mother–child interaction. This coding system had been developed for use in the longitudinal study conducted in Mannheim (Laucht et al., 1997). The interactions were assessed using time sampling. Fixed time intervals of 1, 15, and 30 s, respectively, were used to code the interactive behaviors (see Table 2).

To facilitate the time-intensive coding of the videotapes, a computer program (INTERACT; Mangold, 1998) was used, where the pressing of a previously defined key on the keyboard

TABLE 2. *Microanalytic Rating Scales of the Mother–Infant Interaction*

<i>Mother Rating (Rating per second)</i>	<i>Child Rating (Rating per second)</i>	<i>Joint Mother–Child Ratings (Rating every 15–30 s)</i>
1. direction of gaze at child (2)/at toy (1)/away (0)	6. direction of gaze at mother (2)/at toy (1)/away (0)	9. appropriateness of stimulation (rating every 30 s) overstimulation (2)/appropriate stimulation (1)/understimulation (0)
2. vocalization vocalizes (1)/does not vocalize (0)	7. vocalization positive or neutral (2)/does not vocalize (1)/negative (0)	10. maternal responsiveness (rating every 15 s) facial, physical, vocal, lack of sen- sitivity
3. facial expression positive (2)/neutral (1)/nega- tive (0)	8. facial expression positive (2)/neutral (1)/nega- tive (0)	11. child responsiveness (rating every 15 s) facial, physical, vocal, avoids eye contact
4. content of interaction play or caress (2)/caretaking (1)/ none (0)		
5. proximity near (1)/far (0)		

Note. Where applicable, weights given in brackets.

represented the presence of behavior. If the key was not pressed, the absence of the behavior was recorded by the computer program. The videotape was watched 11 times, once for each scale to be coded.

For statistical analyses, data were transformed into percentages, as not all interactions were of exactly 10 min in duration. Nine scales (Scales 1–9 in Table 1) describing mutually exclusive events were condensed into one variable. For example, the maternal direction of gaze was weighted as follows:

$$\frac{0*(\% \text{ of gaze away}) + 1*(\% \text{ of gaze at toy}) + 2 (\% \text{ of gaze at child})}{(\% \text{ of gaze away}) + (\% \text{ of gaze at toy}) + (\% \text{ of gaze at child})}$$

The weights assigned to the condensed variables are listed in Table 1 and were assigned with reference to the hypotheses as well as previous studies (e.g., reaction is more favorable than no reaction, positive and sensitive interaction is more favorable than a negative interaction or one lacking in sensitivity). Maternal and child responsiveness were not condensed, which left 17 variables (of 33 originally) representing different aspects of the mother–child interaction: one dyadic variable (proximity), six variables both on the mother’s and child’s side (direction of gaze, facial expression, vocalization, facial responsiveness, physical responsiveness, vocal responsiveness), three variables on the mother’s side (appropriateness of stimulation, content of interaction, lack of sensitivity), and one variable on the child’s side (child avoids eye contact) (see Appendix for detailed definitions of the variables).

Good reliability was achieved by three raters (E.R., T.B., D.M.) and the instructor (G.S.). The interrater reliability ranged from $K = .69$ (child facial expression) to $K = .89$ (body distance) across the 11 scales. Continual supervision of the raters was assured throughout the complete rating procedure of the sample. G.S. had been trained by the raters of the Mannheim study in assessing the mother–child interactions and achieved interrater reliability of $K \geq .80$ on the scales. Note that as preterm infants do not tend to signal facially as clearly as full-term

infants, it also may be more difficult for raters to decide upon a facial expression. This fact could result in lower interrater reliabilities with preterm infants than if full-term infants were rated. Field, Greenberg, Woodson, Cohen, and Garcia (1984) also reported these difficulties during the Brazelton examination, wherein faces of preterm infants showed less distinctive codable expressions. The validity was established by comparing the present coding system with the previously developed Mannheimer Beurteilungsskalen zur Erfassung der Mutter-Kind Interaktion im Säuglingsalter (MBS-MKI-S), and demonstrated satisfactory validity (Esser, Scheven, Petrova, Laucht, & Schmidt, 1989). Thus, the MBS-MKI-S contributed to explaining the variance in behavior problems over and above factors of organic and psychosocial risk.

The Nursery NBRS (Brazy et al., 1991; Brazy et al., 1993). This scale was developed to reflect the impact of neonatal medical events on subsequent development of very low birth weight infants and is based on an assessment of conditions that are related to brain cell injury. The following seven items make up the total score: assisted ventilation, blood pH, seizures, intraventricular hemorrhage, periventricular leukomalacia, infection, and hypoglycemia. Scores were allocated on a 4-point scale for each item (0, 1, 2, 4) by the neonatologist. The scores encompassed the intensity and the duration of each risk item. The total score was the sum of the risk items. Some infants were inpatients in several hospitals (Once they were considered stable enough to be moved, they were transferred to a hospital closer to home.); hence, for each in-patient stay, an NBRS score was allocated. The highest total score assigned to the infant during the initial inpatient hospital stay was used for statistical analyses. NBRS scores from rehospitalizations after infants had been discharged were not included here.

The NBRS has been shown to contribute significantly to the prediction of outcome over and above the prediction achieved with the correlated measures of birth weight and gestational age. In the first 2 years of life, the NBRS correlates highly with Bayley's (1969) Mental Development and Psychomotor Indices as well as the Neurologic Examination Score (Amiel-Tison, 1976). An interrater agreement of 97% was shown between two scorers for the NBRS.

The STAI (German version: Laux et al., 1981). The German version of the trait-state anxiety scale was used throughout the study. Two scales with 20 items each assess the *trait* and *state* anxiety of the parents after the birth of their preterm infant. The trait form gives an indication of the amount of pre-event trait anxiety experienced and focuses on the tendency toward a fear/anxiety reaction. The state form of the STAI provides an indication of the amount of anxiety the mother perceived herself as experiencing at a certain point in time. The STAI is a well-standardized and widely used measure for assessing anxiety. Items are rated on a 4-point equidistant scale ranging from *not at all* to *very much*. A separate total score for state and trait anxiety is computed. The stability coefficients for the state scale range from .16 to .54, as could be expected for a measure designed to be influenced by situational factors. Internal consistency (Cronbach's α) of the state scale is reported as high (.85).

Sociodemographic data. In a self-report questionnaire designed for the purposes of the study, mothers were asked about their school qualifications, employment situation, current partner relationship, and whether they had suffered any of a series of stressful life events in recent months (e.g., own ill health, ill health of family member, loss of job, separation from partner). The mothers also were asked about their obstetric history, with a focus on previous pregnancies and births.

RESULTS

Mother–Infant Interactions in Full-Term and Preterm Infants

A multiple analysis of variance was conducted to test whether there was an overall difference in the 17 interaction variables between the preterm sample and the full-term comparison sample. The results revealed a highly significant difference between the interaction of the two samples, $F(17, 94) = 8.24, p \leq .001$, two-tailed, supporting our hypothesis. The small-for-gestational-age infants were included in these and the following analyses, as they did not interact significantly differently from the sample of preterm infants who were appropriate for gestational age, Manova, $F(17, 42) = 1.26$, n.s.

For exploratory purposes, separate Mann–Whitney comparisons were made (17 total) to test in which aspects of the interaction the two samples differed. Only the significant results are listed in Table 3. After the Bonferroni procedure was conducted ($p \leq .05/17 = p = .003$), only those results at a level of $p = .003$ or above are reported as significant. Effect sizes also were calculated using Cohen's formula for d (1988).

Preterm infants vocalized more often and were more vocally responsive when compared to full-term infants. Mothers of preterm infants were facially responsive for less of the interaction, as were their infants. Thus, the results indicated that mothers and infants of the preterm sample were *less* responsive facially than the full-term sample; however, in the vocal channel, the preterm sample was *more* responsive.

Association of Infant's Neurobiological Risk and Mother–Child Interaction

In a first step, to test whether the preterm infant's neurobiological risk influenced the mother–child interaction, a multiple linear regression analysis was conducted. Overall, there was a

TABLE 3. *Mother–Child Interactions of the Premature Sample Compared to Full-Term Comparison Sample*

<i>Interactive Scale</i>	<i>Premature Sample (N = 79)</i>			<i>Full-Term Sample (N = 35)</i>			<i>Effect Size</i>	<i>Mann–Whitney (two-tailed)</i>	
	<i>M</i>	<i>SD</i>	<i>Range</i>	<i>M</i>	<i>SD</i>	<i>Range</i>		<i>Z</i>	<i>p</i>
C. vocalizes	1.21	.17	.53–1.63	1.10	.11	.76–1.32	.68	–3.34	.001*
C. vocally responsive	61.81	25.29	0–97.5	48.14	17.16	17.5–85.0	.59	–3.25	.001*
C. avoids eye contact	1.84	3.59	0–15	.38	1.35	0–6.67	.47	–2.46	.028
M. vocalizes	77.46	15.51	33.17–99.67	72.37	10.52	48.17–89.0	.36	–2.53	.024
M. lacking sensitivity	1.74	7.64	0–62.5	2.43	4.27	0–20	–.10	–2.78	.010
M. facially responsive	59.1	24.66	0–100	75.29	16.80	37.5–100	–.42	–3.25	.001*
C. facially responsive	27.15	20.46	0–72.5	66.51	20.57	22.5–97.5	–1.92	–6.92	.001*

Note. C = Child, M = Mother.

* Significant at a global level .05 after a Bonferroni procedure for 17 variables.

significant trend that neurobiological risk correlated with mother–infant interaction: multiple $R = .57$, $F(17, 61) = 1.75$, $p = .057$.

For exploratory purposes only, the extent to which measures of neurobiological risk influenced aspects of mother–infant interaction was tested in a series of Pearson correlations. Of the 17 separate analyses performed, only one analysis showed a highly statistically significant association: The higher the neurobiological risk of the infant, the more mothers were judged to lack sensitivity (Pearson $r = .349$, $p = .002$, $N = 79$); however, as there was only a significant trend in the multivariate analysis, the individual results should be treated with extreme caution.

Association of Maternal Anxiety and Mother–Child Interaction

From our clinical experience as well as from the literature, the question arose if and to what extent maternal state anxiety played a part in influencing the quality of the mother–infant interaction. Before testing the hypothesis that maternal anxiety was associated with the mother–child interaction, we wanted to test whether mothers of preterm infants were in fact very anxious after their preterm infant’s birth. Table 4 shows the maternal anxiety levels in the first months.

Note that the data collected at T3 is excluded from here on due to the extent of missing data. This missing data may be explained by parents being preoccupied by the imminent discharge of their infant and thus neglecting to fill out the questionnaire. But a sample of German mothers with healthy full-term infants had a much lower anxiety score (STAI score $M = 32.1$, $SD = 8.1$, $N = 36$) at 3 months’ postpartum (Munz, 2000) when compared to the sample of mothers of preterm infants.

Over time, the measurement of the level of the mother’s state anxiety demonstrated a reduction in the preterm sample. To test whether this reduction was significant, a repeated measures MANOVA was conducted over three assessments (T1, T2, T5). Results indicated that the reduction in the levels of anxiety over time was highly significant, $F(2, 62) = 21.27$, $p \leq .001$; neurobiological risk was taken as a covariate, $F(2, 62) = .66$, n.s. Thus, independent of how ill the preterm infant was, mothers’ anxiety lessened over time.

Maternal factors, which might have contributed to the state anxiety levels of the mothers at the time of interaction with her child (at T5), were examined to eliminate possible confounding variables. The age of the mother, whether she had previous premature births or miscarriages, parity, level of education, and previous life events were not significantly associated with measured anxiety level at T5.

At 3 months’ corrected age (T5), the anxiety level of the mother was significantly associated with the gestational age of the preterm infant, Spearman $\rho = -.33$, $p = .004$, $n = 74$, but the infant’s birth weight (excluding the small-for-gestational-age infants) was not. The

TABLE 4. *Maternal Anxiety Scores From Birth to 3 Months’ Corrected Age*

<i>Time of Maternal Anxiety Assessment</i>	<i>M</i>	<i>SD</i>	<i>n</i>	<i>Min</i>	<i>Max</i>
After birth (T1)	50.46	13.14	76	25	79
1 month after T1 (T2)	47.11	13.53	71	26	80
before discharge from the hospital (T3)	46.38	13.52	53	22	75
3 months corrected age of premature infant (T5)	38.86	12.38	74	21	78

Note. Sample size varies as not all participants filled out the questionnaire completely.

TABLE 5. *Mother–Child Interactions and the Association of Maternal Anxiety and Neurobiological Risk*

<i>Interactive scale</i>	<i>Maternal Anxiety</i> <i>Pearson</i>		<i>Partial Correlation Controlling</i> <i>for Neurobiological Risk</i>	
	(<i>n</i> = 74)	<i>p</i>	(<i>n</i> = 71)	<i>p</i>
M. lacks sensitivity	.254	.029	.182	n.s.
M. vocalizes	.239	.04	.220	n.s.
C. facially responsive	–.372	.001*	–.320	.006
C. vocally responsive	–.264	.023	–.243	.038
C. facial expression	–.284	.014	–.238	.042

Note. *n* = 71 where data is available for both the infant’s neurobiological risk score and maternal anxiety.

* Significant at a global level .05 after a Bonferroni procedure for 17 variables.

lower the gestational age of the infant, the higher the mother’s anxiety level. The neonatal risk of the infant as determined by the NBRS also was correlated with mother’s anxiety at T5, Spearman $\rho = .26$, $p = .03$, $n = 74$. Mothers rated themselves as more anxious with greater neurobiological risk for their infant.

Overall, the effect of maternal anxiety at the time of the interaction (T5) on the mother–child interaction was significant using a linear regression, multiple $R = .625$, $F(17, 56) = 2.11$, $p = .019$. Measures of anxiety after birth of the preterm infant (T1) and 1 month later (T2) did not demonstrate significant associations with the mother–child interaction at 3 months’ corrected age (T5); therefore, only the anxiety assessment at 3 months’ corrected age will be of interest from here on.

For exploratory purposes, a series of individual correlations was conducted, but only one was statistically significant at the level of $p = .003$ or above (see Table 5 for details). Results indicated that mothers with high anxiety had children who were less facially responsive, Pearson $r = -.372$, $p = .001$, $n = 74$, than infants of mothers with lower anxiety levels. The remaining results are significant trends.

We wanted to test whether our significant finding could be further explained by the influence of the neurobiological risk status of the infant. Partial correlations controlling for the effect of the neurobiological risk demonstrated that risk played some part in the relation between maternal anxiety and the mother–child interaction, as it at minimum reduced the significance of the interaction. Nevertheless, a stronger association was evident in the relationship between maternal anxiety and the mother–child interaction. Therefore, maternal anxiety more than the premature infant’s neurobiological risk should be taken into account and treated when assessing the influence of a premature birth on the mother–infant interaction.

DISCUSSION

As hypothesized, the results revealed that there are significant differences in the mother–infant interactions in the preterm sample when compared to the full-term sample. More specifically, the preterm infant sample was more vocally active and responsive than the full-term sample; however, in the facial or visual channel, the preterm infants and their mothers are less facially responsive during the interaction. Hence, the ability to be more or less responsive appears to depend on the channel of communication. Similarly, Barratt, Roach, and Leavitt (1992) in their sample ($N = 34$) of comparatively healthy preterm infants (birth weight $M = 2,099$ g, gesta-

tional age $M = 34$ weeks, stay in hospital $M = 17$ days, 7 infants experienced transitory respiratory distress) found mothers to be particularly sensitive to their preterm infants' vocal signals. We suggest that the vocal channel may be particularly used or preferred by preterm infants and their mothers and compensates for the less responsive facial interactions.

While the present sample is more at risk than the Barratt et al. (1992) sample, similar mechanisms of communicating via the vocal channel as opposed to the facial one seem to apply. Esser et al. (1996) stressed the importance of eye contact for sensitive interaction between mothers and infants. They found that for infants who look elsewhere apart from their mother, results suggested a developmental path that led to later cognitive or motor deficits, and thus implied that disturbed facial communication is a marker for later difficulties. Further research can elucidate to what extent the vocal channel can compensate for less facial responsiveness and whether this compensation would impact the developmental path of a child.

A limitation of this study was that analyses of 17 mother–child interaction variables led to few statistically significant findings; however, the advantage of keeping the interaction variables separate, as opposed to using a conglomerate measure, is that the findings are more transparent. In addition, a possible confound and therefore limitation of the study may be that the schooling of the two samples differs. The mothers in the full-term sample were at school longer than the mothers in the preterm sample; however, as other studies also have shown the differences between full-term and preterm samples we found in our study, this may be of limited concern.

Even though only one significant trend was found, it suggested that mothers in the full-term sample appear to lack sensitivity for more of the interaction when compared to the preterm mothers. This result lends support to studies that show that mothers of preterm infants tend to be more responsive and attuned to their infants than mothers of full-term infants (e.g., Crawford, 1982; Greene et al., 1983). Greene et al. (1983) found that mothers of preterm infants at 3 months' postterm age were more vocally responsive to their infants than were mothers of full-term infants. Additionally, maternal behavior continued to be influenced by the birth history of the infant at 3 months, even though no difference was seen in the infant's behavior at that time. Since our results do not reach significance and suggest a trend only, caution is necessary in further interpretation of these results.

We also wanted to assess the influence of maternal anxiety on the mother–infant interaction, as anxiety is known to accompany the birth of VLBW preterm infants (Catlett, Miles, & Holditch-Davis, 1994; Cobiella et al., 1990; Gennaro, 1988). Overall, anxiety was significantly associated with the mother–infant interaction. The more anxious a mother, the less likely the infant was to demonstrate facial responsiveness. All trends suggested that high anxiety is not conducive to sensitive and responsive interactions; however, a bidirectional effect between maternal anxiety and the mother–infant interaction may be assumed; that is, if a child shows little facial responsiveness, mothers may react with more anxiety. Equally, mothers who are more anxious may be less emotionally available to the infant, leading infants to be less responsive in the interaction (for discussion of bidirectional effects, see Dunn, 1997).

In this sample of VLBW mothers and their infants, the level of anxiety was very high in the first week after premature birth. This level decreased in the following months, and at 3 months, the mean level was comparable to the level of anxiety of mothers with a normal full-term birth (although some mothers still had very high levels of anxiety). Thus, associations with maternal anxiety and the mother–child interaction scales were weak. The decrease of anxiety over time may be explained by most preterm infants having overcome many of the difficulties they experienced at the beginning of their life (e.g., artificial ventilation, operations, difficulties feeding, infections). Over time, mothers adjusted to the situation of having a preterm infant. In the first month after the birth, Singer et al. (1999) also found the level of maternal

psychological stress and life stress to be significantly higher in mothers with a high-risk preterm infant (with bronchopulmonary dysplasia) when compared to mothers of term infants. Over 3 years, psychological distress abated and was comparable to that of term mothers.

Partly for practical reasons, the mother–infant interaction was filmed once at 3 months' corrected age, and not earlier when maternal anxiety level was at its peak. If mother–infant interactions were recorded when maternal anxiety was higher (i.e., in the first 2 months after birth of the preterm), a stronger association between anxiety and mother–infant interaction may have been demonstrated. Additionally, if the neurobiological risk had been assessed again at 3 months' corrected age, there may have been a stronger association with the mother–infant interaction than found at present.

Results from our study indicated that maternal anxiety also was associated with the infants' biological risk (also see Blumberg, 1980). Mothers are more anxious the earlier the infant is born (low gestational age) and the higher the NBRS score. To date, infants may survive from 23+ weeks gestation, and it is known that the longer a mother carries her baby (if there are no complications), the better it is for the infant's health. Interestingly, birth weight was not significantly associated with maternal level of anxiety. Since no specified weight indicates survival of a newborn (Weiss, Walcher, Hüttner, & Winter 1998), this view may account for the evident lack of association with maternal anxiety in this VLBW sample.

Differences found between the preterm and the full-term samples may be explained by different raters assessing the different samples; however, as all the raters were trained by the same procedure, this probability should be reduced. One of the raters of the preterm sample (D.M.) assessed the interactions of a sample of mothers of full-term infants ($N = 45$) using a shortened version (encompassing seven variables) of the mother–infant assessment. No significant differences were found in the ratings of the interactions between these mothers of full-term infants and mothers of the full-term infants from the Mannheim sample on the available variables. This finding provides further evidence that the likelihood of differences found between the samples was not due to different raters but was instead attributable to the effect of the infant's maturity.

Speculations as to why the psychotherapeutic intervention (Brisch et al., 1996) did not reduce maternal anxiety might be explained by the conceptualization of this intervention, which may have lacked specificity. Although mothers in our intervention group had contact with the psychologist/doctor once a week for 50 min, ostensibly addressing their anxiety, the number of sessions was perhaps too little or not specific enough to mitigate the anxiety associated with a preterm birth. The individual sessions of our intervention program (five sessions maximum) provided an opportunity to examine previous losses, but did not provide a long-term approach that might lead to representational changes or focus on maternal anxiety specifically. Reducing the high levels of maternal anxiety especially in the first months of the preterm infant's life should be a special focus for psychotherapeutic intervention. While we did not establish a causal relationship, higher levels of maternal anxiety are associated with less favorable interaction. This study has concentrated on the differences in the interaction of preterm and full-term infants according to the defined variables in the mother–child interaction. There are, of course, additional ways of interacting and measuring emotional states than by the variables assessed here. We do not claim to have captured the full range of neurobehavioral responses of the preterm or full-term population, and therefore the study has its limitations.

Clinical practice may consider the following aspects of the study as particularly relevant: As high levels of maternal anxiety are associated with less favorable mother–infant interactions, mothers could be offered a stress-reduction treatment to reduce their anxiety levels. Cobiella et al. (1990) were successful in teaching mothers of preterm infants relaxation techniques and cognitive coping strategies that have in turn resulted in a decrease of anxiety levels.

To conclude, the most significant differences in the mother–infant interactions were found between the preterm and the full-term samples. The influence of maternal anxiety on the interaction also was documented, and the results are in tune with previous findings, where high levels of maternal anxiety are not conducive to positive mother–child interactions (Gennaro, 1988; Gennaro et al., 1990; Whaley et al., 1999). The neurobiological risk of the infant assessed in the first weeks of the his or her life had a negative influence on the mother–infant interaction, but this effect was less strong than that of maternal anxiety. Due to some limitations of the study, it would be desirable if the results of the differences between the preterm and full-term samples could be replicated. Perhaps premature infants use the vocal channel to compensate for less visual communication, and this may not have any unfavorable long-term consequences. Further research should concentrate on the implications of communicating more with the vocal as opposed to the facial or visual channel for the prematurely born child's later development.

APPENDIX

Definition of Joint Mother–Child Interaction Ratings

Maternal Responsiveness is defined as maternal behavior, which is a sensitive reaction and appropriate to the child's interactive needs. Responsiveness is categorized according to the different expressive channels (facial, physical, and vocal).

Child Responsiveness is defined as a behavior, where the infant responds to maternal behavior. Responsiveness is categorized according to the different expressive channels (facial, physical, and vocal).

Appropriateness of stimulation: Behavior is defined as *appropriate* when it fulfills in its intensity, content, and level of difficulty the current requirements of the infant.

Behavior is defined as *overstimulation* when mothers stimulate the child too much, taking the activity level of the child and its interactive availability into account.

Behavior is defined as *understimulation* when mothers stimulate the child too little, taking the activity level of the child and its interactive availability into account.

Lack of sensitivity: Mother does not see marked negative signals of the infant nor does she respond to interactive offers of the infant.

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