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Interactive sequences between fathers and preterm infants in the neonatal intensive care unit

Alberto Stefana[a,*], Manuela Lavelli[b], Germano Rossi[c], Beatrice Beebe[d]

[a] Independent researcher
[b] Department of Human Sciences, University of Verona, Lungadige Porta Vittoria 17, 37129 Verona, Italy
[c] Department of Psychology, University of Milan Bicocca, Piazza dell'Ateneo Nuovo 1, 20126 Milano, Italy
[d] Department of Psychiatry, New York State Psychiatric Institute, 40 Haven Avenue Unit 78 New York, NY 10032, USA

A B S T R A C T

Aims: The first purpose of the study was to examine fathers' spontaneous communicative behavior with their preterm infants in the neonatal intensive care unit, and how father's and infant's behaviors affected each other. The second purpose was to examine any possible association between the fathers' and/or infants' characteristics and the quality of fathers' behaviors with their infants.

Study design/Subjects/Outcome measures: Father–preterm infant dyads (n = 20) were assessed at 34-36 weeks postmenstrual age, during a spontaneous face-to-face communication with the infant placed in a heated cot in the NICU, and coded according to the Parent-Preterm Infant Coding System.

Results: The presence of the father's Affiliative Behavior increased the occurrences of infant Gazing at the parent's face. In turn, infant gazing increased the occurrence of paternal Affiliative Behavior. The likelihood of infant's Gazing at the father's face was also significantly elicited by infrequent occurrences of paternal Affectionate Talk, co-occurring with Gazing at infant with Positive Facial Affect (but no Touch). With regard to the predictors of quality in father–infant interactions, we found a significant positive correlation between fathers' level of depressive symptomatology and fathers' Affiliative Behavior.

Conclusion: Our results show the of bidirectional sequential patterns of communication between fathers and preterm infants at 35 weeks postmenstrual age, and provide important information about the quality and modalities of paternal communication and their influence on infant behavioral states. From a clinical perspective, these results suggest that father-specific interventions designed to improve and sustain fathers' positive engagement with infants in the NICU should be pursued.

Newborns are biologically equipped to selectively interact with others [1]. Such pre-adaptation of the newborn to social interactions [2–4] includes both perceptual and expressive capacities. With regard to perceptual capacities, there is a remarkable continuity between pre- and postnatal development [5–7]. For example, the fetus develops a tactile sensitivity from the beginning of the 9th gestational week [8,9] responds to sound from the 19th gestational week [10–12] and responds to touch on the abdomen with a selective increase of arm, head, and mouth movements in the 21st–25th gestational weeks [13,14]. Furthermore, beginning around the 25th gestational week, the fetus has the ability to process *visual*-perceptual information and shows a preference to engage with face-like stimuli [15].

Thanks to the fact that cognitive-motor control of the eyes is relatively advanced (compared to other motor abilities) [16], healthy preterm neonates can benefit from early – and therefore longer duration of – exposure to visual experiences of face-to-face interaction. Remarkably, these healthy preterm neonates can develop the capacity for gaze following sooner than term infants of the same postmenstrual age [17]. For preterm neonates, gaze is the central mode of establishing communication with caregivers [17].

The literature on infants born at term is consistent in finding that mother–infant spontaneous face-to-face communication is in play as a mutual regulation system from the first weeks of life [18–20]. Comparable studies of spontaneous communication between parents and preterm infants in the first weeks of life have not been conducted.

Studies conducted with preterm infants in the early months of life document that, because of their neurological immaturity, these infants tend to spend less time in alert states, to be less responsive during social exchanges, and to send less clear communicative signals than term infants [21]. As a consequence, caregiver-preterm infant interactions have been found to be less mutually responsive and adaptive than those between term infants and their caregivers during the first semester of life [22–24].

Positive parent–preterm infant bonding can overcome negative impacts of premature birth [25], an effort that can be increased in the NICU [26]. For example, recent studies show dramatic positive effects after immediate skin-to-skin and breastfeeding following preterm birth [27]. More generally, facilitating early nurturing interactions and

* Corresponding author at: Via Fratelli Bandiera 10, 25122 Brescia, Italy.
E-mail address: alberto.stefana@email.it (A. Stefana).

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emotional connection between mothers and their preterm infants is an effective mean of optimizing postnatal biobehavioral development in preterm infants, providing a neurophysiological platform for optimal infant–caregiver co-regulation [28–30].

Regarding early parent–preterm infant interaction in the NICU, voice may become a particularly salient channel through which to create and maintain emotional connection [31–33]. Indeed, the exposure to maternal voice – live or recorded, and administrated in different ways – has been found to increase preterm infant waking states and attending behaviors by 31 weeks [34], quiet alert state at 32 weeks [35], open eyes by 32 weeks [36], and later visual and auditory orientation at 3 months CA [37]. More generally, there is strong evidence of the beneficial effects of early exposure to the human voice on a large spectrum of preterm infants' developmental outcomes [38,39]. Nonetheless, it should be highlighted that the research on exposure to paternal/male voice is sorely lacking [40,41].

To date, paternal spontaneous social behaviors with their preterm infants in the NICU have not been investigated. Actually, very few studies [42–45] have explored parents' (usually mothers') spontaneous social communication with their preterm infants in the NICU. Among these studies, the communication was assessed prior to discharge from the NICU, when the infant was able to spend some time out of the incubator. One study has documented maternal adaptation of affiliative behavior to preterm infant alert states (co-occurrence), during social interaction at 37 weeks. However, this study did not assess mutual regulation, that is, how mother behavior may affect infant behavior, and vice versa [45].

Another study, the Family Nurture Intervention (FNI) randomized clinical trial [46], has prioritized the emotional connection between mother and preterm infant. The FNI intervened with maternal caregiving behavior, beginning while the infant was still confined to the incubator in the NICU. It employed three categories of activities that were facilitated by nurture specialists: calming interactions via reciprocal odor cloth exchange, firm sustained touch and vocal soothing, and eye contact while the infant was placed in the incubator; calming interactions during feeding, skin-to-skin holding or non-skin-to-skin holding; and family sessions specifically designed to engage, help and support the mothers. This intervention predicted increased positive engagement in mothers and infants during 4-month face-to-face communication [47]. Furthermore, the FNI project found that more sensitive maternal caregiving and higher quality of vocal contact during diaper change, holding and feeding sessions prior to NICU discharge (at 36 weeks GA) was associated with higher levels of maternal emotional connection measured by the Welch Emotional Connection Screen at 4 months CA [48].

After preterm birth, mothers require a recovery period that does not allow them to be close to their infants during their first days in the NICU. Thus fathers can potentially play a crucial role [30]. However, fathers can face many obstacles in this role, such as experiencing emotional withdrawal, worry over loss of control, concern for both the infant's and mother's health, seeing their preterm infant as “insanely small” [49]. With regard to this perception, earlier findings based on interviews with fathers from the same research project revealed that fathers were struck by their infants' physical appearance; interestingly, higher levels of fathers' fear that touching their preterm infants might cause rupture, damage or physical pain were significantly associated with infants' lower gestational age [49]. Finally, fathers may have difficulty finding a balance between job and infant involvement [50], with possible negative consequences for their engagement in the care of the infant [49,51] and the onset of father-infant interaction [45,52,53]. Since fathers' interactive behaviors (in terms of sensitivity, intrusiveness, or withdrawal) with their preterm infants tend to remain more stable than mothers' interactive behaviors, from birth to 24 months [54], an analysis of early paternal communication with the preterm infant could identify early indices of risk in the developing father-infant relationship. Nevertheless, most studies and support programs concentrate on preterm infants and their mothers, usually failing to include fathers [55]. Father-preterm infant interaction has rarely been investigated [45,56–58]. Only one study [44], to our knowledge, as considered father-infant interaction in the NICU. Nevertheless, the literature has shown positive consequences of father-infant interaction for infant development [59,60].

Finally, compared to mothers of term infants, mothers of preterm infants are at greater risk for postpartum depression [61–64], a condition that negatively affects the development of mother–infant interaction and infant developmental outcomes [65,66]. Maternal depression is associated negatively with the quality of maternal behavior during interaction with their preterm infants [67–69]. The few studies that have examined paternal depression in the postnatal period were conducted with term infants, and the results showed that father's depression dampens father–infant interaction [70–72].

In the light of the above literature, this study focused on father-infant spontaneous face-to-face communication with preterm infants who were confined to the heated cot in the NICU, at 35 weeks PMA. We had two hypotheses:

1. We expected to find bidirectional sequential patterns of communication between fathers and infants. In particular:
   1a) on the basis of the literature showing increased open-eyes of preterm infants exposed to maternal voice, we hypothesized that paternal affectionate multi-modal stimulation that specifically includes the father's voice, increases the likelihood of infant open-eyes and gaze toward the father;
   1b) based on a prior study [45] showing the co-occurrence of maternal affiliative behavior and the preterm infant alert state, we hypothesized that the infant alert state with open-eyes oriented toward the father increases the likelihood of paternal affectionate communicative behaviors.
2. We expected father's depressive symptoms to affect the quality of father–infant interaction. Specifically:
   2a) on the basis of the literature showing that both maternal and paternal depression in the postnatal period dampens parent–infant interaction, we hypothesized that father's depressive symptoms predict decreased affiliative behavior during father–infant interaction in the NICU;
   2b) based on a prior study [49] showing an association between infant gestational age and paternal fear of harming the preterm infant by touching the infant, we also hypothesized that lower infant gestational age could contribute, along with father's depressive symptoms, to decreased paternal affiliative behavior. Specifically, we hypothesized that interacting with an infant who has a very small body size increases the likelihood of paternal concern about harming the infant, generating more withdrawn paternal behaviors.

1. Method

1.1. Participants

Twenty father–infant Italian dyads participated in the study [73]. All 20 infants were healthy preterms born 27–33 weeks gestational age and hospitalized in the NICU. Exclusion criteria included perinatal asphyxia, neurologic pathologies (periventricular leucomalacia up to stage I and/or intraventricular haemorrhage up to stage II), malformation syndromes and/or major malformations, sensory deficits, metabolic or genetic disease. Dyads were recruited at the level III NICU in Verona, Italy. Fathers were eligible if they were biological parents, born and raised in Italy, with no psychiatric illness or habitual drug abuse. Fathers' and infants' demographic and clinical characteristics are detailed in Tables 1 and 2, respectively. The study was approved by the Ethical Committee for Clinical Trials of the Verona and Rovigo Provinces (reference no. 569CESC).

Table 1
Fathers' characteristics.

	M (*SD*)
Age (years)	39.5 (4.7)
First-time parent	65% (13)[a]
CES-D scores	15.1 (8.7)
DAS scores	117.9 (8.6)
Socioeconomic status	3.0 (0.7)
Range	1.8–4

Note. CES-D = Center for Epidemiologic Studies Depression scale; DAS = Dyadic Adjustment Scale.
[a] *% (n)*.

Table 2
Infants' characteristics.

	n (%)
Birth status	
Singleton	8 (60%)
Twin (couples)	6 (40%)
Type of birth	
Vaginal	1 (5%)
Cesarean	19 (95%)
Infant gender	
Males	8 (40%)
Females	12 (69%)

	M (*SD*)
Gestation at birth (weeks)	31 (2.1)
Range	27–33 + 5
Birth weight (kg)	1.450 (0.411)
Range	0.650–2.100
Infant weight (kg) when videotaped	1.999 (0.253)
Range	1.530–2.290
Infant age (days) when videotaped	30 (15)
Range	9–58

1.2. Procedure

All fathers completed the Italian version of the Center for Epidemiologic Studies Depression Scale (CES-D) [74] to assess current level of depressive symptomatology [75], the Italian version of the Dyadic Adjustment Scale (DAS) [76] to evaluate distress within the marital relationship [77] and a questionnaire on socio-demographic information.

Then, father–infant dyads were videotaped during spontaneous face-to-face communication in the NICU when healthy preterm infants (a) were between 34 and 36 weeks postmenstrual age (M PMA 35.3 weeks, SD 0.4, range 34.7–35.9) and (b) were transferred from incubators to open heated cots (having reached a weight of at least 1600–1800 g which allows them to maintain thermoregulation). The father, who was face-to-face with the infant, was asked to interact with the infant freely; no specific instructions were given.[1] The interaction was videotaped for 3 min, and filming began when the infant was in an awake and calm state. Due to fathers' work commitments, there was no specific time of the day that interactions were videotaped. Researcher and fathers decided a meeting time on the basis of the particular needs of each father, and then they waited until the infant was awake. When this condition was not met during the first appointment, a new appointment was set for the following day.

1.3. Coding

Father and infant behaviors during the videotaped interaction were coded microanalytically, using units of 1 s [22,78–80]. Coding was conducted using the Parent-Preterm Infant Coding System specifically devised by Lavelli and Beebe [81], a system for coding parent-preterm infant interaction in the NICU, on a 1 s time-base. The coding system includes the *Parent Engagement Scale,* comprised of 8 mutually exclusive categories, in an ordinal scale from the most complete configuration of Parental *Affiliative Behavior* [45,82] (i.e., co-occurrence of Gaze at Infant, Affectionate Touch, Affectionate Talk, and Positive Facial Affect) to Gaze Off; and the *Infant Engagement Scale,* comprised of 7 mutually exclusive categories in an ordinal scale from Gaze On + Smile to Negative Expression. See Tables 3 and 4 for detailed descriptions.

1.4. Reliability

Inter-coder reliability for infant behaviors and paternal behaviors was calculated on a random sample of 4 of the 20 sessions (20%). The average Cohen's kappa was 0.86 (range: 0.80–0.93) for infants' behaviors, and 0.79 (range: 0.73–0.84) for fathers' behaviors.

1.5. Statistical analysis

A sequential analysis (GSEQ, Generalized Sequential Querier) [83] was performed on the infant's behaviors as *target* and the father's behavior 1 s prior as *given*, and vice versa, to assess whether paternal affectionate behaviors including the father's voice increase the likelihood of infant open-eyes oriented toward the father, and vice versa. The analysis was performed on father-infant dyads as a group, using a lag of 1 s. The significance of transitional probabilities between father and infant behaviors was assessed using z scores (adjusted standardized residuals) proposed by Haberman [84], further controlled by the Haberman condition (sum of row frequencies > 30 and transitional probability between .10 and .90). In addition, following Bakeman & Quera's [85] suggestion for analyses with elevated number of cells and/or frequencies, we adopted a more conservative approach by considering the threshold of $z > 3.00$ ($p < .001$) for significance.

To test the second hypothesis, a hierarchical regression analysis was computed using the frequency of seconds of fathers' Affiliative Behavior (i.e., co-occurrence of Gaze at Infant, Affectionate Touch, Affectionate Talk, and Positive Facial Affect, coded as behavioral configuration #8) as target, fathers' depressive symptoms (CES-D scores) as a main predictor, and infants' gestational age as another possible predictor. Because of the small sample size, the analysis was conducted using the robust method of bootstrapping [86], with 5000 bootstrap samples to generate confidence intervals and significance tests of the model parameters.

2. Results

Descriptive statistics for fathers' and infants' behaviors are reported in Table 5.

2.1. Early interactive sequences (Hypothesis 1)

With regard to our main hypothesis, sequential analysis revealed significant reciprocal transitional probabilities between father's and infant's behaviors indicating the presence of early interactive sequences, during the father's spontaneous communication with the preterm infant confined to the heated cot in the NICU.

Fig. 1 depicts the real-time transitional probabilities between

[1] Within the NICU's routine practice, parents are provided with oral and written information about the most appropriate behaviors to use during interactions with a preterm infant, according to the infant's gestational age. For example, the 'parents information booklet' provided parents with a range of behaviors that should be undertaken with their infants in the different phases of the NICU journey, such as "At 30-32 weeks I will be able to see you at a distance of 20-30 centimeters", and, "You must use a firm but gentle touch, without rubbing".

Table 3
Parent Engagement Scale.

Behavioral configuration	Description
8. Gaze on–Affectionate Touch–Affectionate Talk–Positive Facial Affect[a]	Parent is gazing at the infant, touching and talking to her/him in an affectionate way. Affectionate Touch includes still warm touch,[b] stroking, and stroking combined with gentle tactile or gentle kinesthetic stimulation. Affectionate Talk includes "baby talk" vocalizations. Facial expression is positive.
7. Gaze on–Affectionate Touch–No Talk–Positive Facial Affect[a]	Parent is gazing at the infant, touching her/him in an affectionate way (see above). Facial expression is positive.
6. Gaze on–No Touch–Affectionate Talk–Positive Facial Affect[a]	Parent is gazing at the infant, without touching her/him, but talking to her/him in an affectionate way including "baby talk". Facial expression is positive.
5. Gaze on–Affectionate Touch–No Talk–Neutral Face	Parent is gazing at the infant, touching her/him in an affectionate way (see above). Facial expression is neutral
4. Gaze on–No Touch–No Talk–Positive Facial Affect	Parent is gazing at the infant, without touching and/or talking to her/him, but showing positive facial expression.
3. Gaze on–No Touch–Talk/No Talk–Neutral Face	Parent is gazing at the infant, without touching her/him. Parent could talk in a non-affectionate mode including flat, adult-directed speech. Facial expression is neutral.
2. Gaze on–Non-Affectionate Caregiving Touch–Talk/No Talk–Neutral Face	Parent is gazing at the infant, touching her/him in a non-affectionate way including caregiving or rough touch. Parent could talk in a non-affectionate mode including flat, adult-directed speech. Facial expression is neutral.
1. Gaze off	Parent is gazing away from the infant.

Note.
[a] Behavioral configurations #8, 7, and 6—that is, a combination of Gaze at the infant, Affectionate Touch and/or Affectionate Talk, and Positive Facial Affect–constitute the Parental Affiliative Behavior [45,82].
[b] In the NICU context parental Static Touch as firm and sustained touch is an effective and salient way to be in contact with the preterm infant [46,47], given the loss of physical contact with the parent and the prolonged separation that results from the NICU experience; therefore, otherwise that with full-term infants, Static Touch is considered as Affectionate Touch.

paternal and infant behaviors found to be significant. During father-infant interaction the presence of the father's Affiliative Behavior (i.e., co-occurrence of Gazing at infant with Positive Facial Affect, Affectionate Touch and Affectionate Talk) increased the likelihood of infant Gazing at the father's face. In turn, infant Gazing at the father's face increased the likelihood of paternal Affiliative Behavior, indicating a bidirectional link between paternal affectionate, multi-channel communicative behavior and infant visual engagement. Father's Non-Affectionate Caregiving Touch increased the likelihood of infant alert state with open-eyes gazing at the surrounding environment. In turn, this infant alert state with open-eyes Gazing at the environment, increased the likelihood of paternal Affectionate Touch co-occurring with Gazing at infant with Positive Facial Affect (but not Affectionate Talk).

2.2. Predictors of paternal affiliative behavior (Hypothesis 2)

With regard to the second hypothesis, a hierarchical regression analysis conducted through bootstrapping was computed predicting fathers' Affiliative Behavior from father depressive symptoms and infant gestational age. Father depressive symptoms score was entered on the first pass as a main predictor, and infant gestational age was entered on the second pass. Table 6 shows that the combination of these variables (Model 2) explains 30% of the variability in fathers' Affiliative Behavior. Although the only significant predictor is fathers' level of depressive symptoms, infants' gestational age contributes to increasing the

Table 5
Descriptive data for fathers' and infants' behaviors (in seconds) during 180 s of father-infant face-to-face interaction.

Fathers		
Behavioral configuration	*M*	*SD*
8. GazeOn + AffectionateTouch&Talk + PositiveFacialAffect	49.00	29.77
7. GazeOn + AffectionateTouch + PositiveFacialAffect	58.90	38.39
6. GazeOn + AffectionateTalk + PositiveFacialAffect	1.90	4.47
5. GazeOn + AffectionateTouch + NeutralFace	50.60	46.47
4. GazeOn + PositiveFacialAffect	5.85	9.58
3. GazeOn + NeutralFace	3.85	5.52
2. GazeOn + NonAffectCaregivingTouch + NeutralFace	6.65	13.65
1. GazeOff	3.75	4.09

Infants		
Behavioral configuration	*M*	*SD*
7. GazeOn + Smile	0.30	0.80
6. GazeOn + NeutralFace	54.50	47.01
5. GazeOnEnvironment	19.65	18.68
4 + 3. GazeOff + NeutralFace or HeadAverted	39.20	40.56
2. EyesClosed	65.20	63.81
1. NegativeExpression	1.45	4.41

Table 4
Infant Engagement Scale.

Behavioral configuration	Description
7. Gaze on–Smile	The infant is gazing at the parent's face and smiling.
6. Gaze on–Face neutral	The infant is gazing at the parent's face with no particular facial action (except for reflexes and vegetative movements).
5. Gaze on environment	The infant is gazing at the surrounding environment.
4. Gaze off–Face neutral	The infant's gaze is oriented elsewhere from the parent's face but not active (i.e., eyes are open but gaze is vague); no particular facial action (except for reflexes and vegetative movements).
3. Gaze off–Head averted	The infant is keeping her/his head and gaze averted from the parent's face.
2. Eyes closed	The infant's eyes are closed. Eyes closed for vegetative movements such as sneezing and yawning are included.
1. Negative Expression	The infant is showing any vocal and/or facial negative expression (grimace, pre-cry, fussy, crying) and/or body negative expression (squirmy, agitated), either with gaze-on or off, and eyes open or closed.

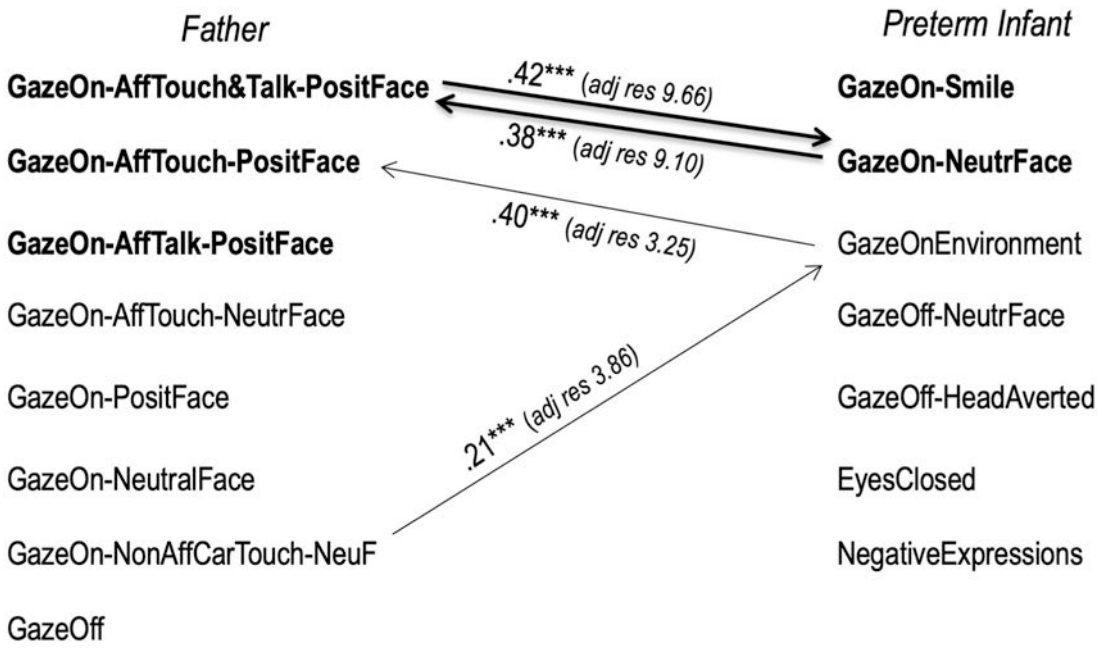

Fig. 1. Real-time transitional probabilities between paternal and infant behaviors.
Note. Mean transitional probabilities between father's and preterm infant's behaviors during 3 min of paternal communication with the preterm infant in a heated cot, in the NICU. Only transitional probabilities found to be significant at the threshold of adjusted standardized residuals > 3.00 (***$p < .001$) are included.

percentage of variance accounted for (R2).

3. Discussion

This study increases our understanding of the early development of bi-directional interactive sequences between fathers and their preterm infants, and factors that affect fathers' communicative behaviors with these infants.

Our first hypothesis was confirmed, that fathers and preterm infants show spontaneous bidirectional sequential patterns of communication at infant 35 weeks PM. These pattern of communication were documented when infants who showed stabilized medical conditions were able to leave the incubator but were still confined to an open heated cot in the NICU. We knew from the literature on term infants that parent–infant mutual attention starts as early as the first two weeks of life with a bidirectional link between infant's gaze on mother's face and maternal affectionate talking [19]. Our study now documents that even preterm infants show a bidirectional pattern of communication in the first weeks of life.

The transfer from the incubator to the new cot context allows parents easier access to their babies. The heated cot may therefore be important in establishing caregiver–infant interactions, which are essential to infant social and cognitive development, and regulation of the stress response [87–89]. In particular, microanalytic coding and sequential analysis of father–infant communication with preterm infants in the heated cot revealed that paternal affiliative behavior – i.e., affectionate touch and talk while gazing at the infant's face with positive facial affect – increases the likelihood of the infant's gazing at the father's face. Infant gaze, reciprocally, elicits paternal affiliative behavior. This result indicates that multiple co-occurring channels of affectionate social stimulation are effective in increasing the likelihood of the preterm infant's engagement.

Taken as a whole, the findings from the sequential analyses suggest that a combination of affectionate social stimuli is more effective than unimodal stimulation. Moreover, the findings suggest that father's Affectionate Talk (which generally occurred with Affectionate Touch) might have a special role in engaging the preterm infant. Indeed, father Affectionate Touch co-occurring with Gazing at infant with Positive Facial Affect, but no Affectionate Talk, was not sufficient to increase the likelihood of infant engagement. We hypothesize that particularly the low-pitched sounds of the male voice might have been crucial in eliciting the preterm infant's gaze at the father's face. This is supported by studies on preterm infants' responses to auditory stimulation, which demonstrate that infants between 32 and 35 weeks post-conception can discriminate between male and female voices [90] and respond to the lower pitched sounds of the male voice with decreased heart rate

Table 6
Predicting fathers' affiliative behavior.

Model[a]	*R*	R^2	*Adjusted* R^2	*Std. Error*	*F (df)*	*p*	*Beta*	p_*
1	.547[b]	0.299	0.260	25.59	7.69 (1,18)	0.013		
(constant)								0.1340
F CES-D							0.547	.025
2	.610[c]	0.372	0.299	24.93	5.04 (2,17)	0.019		
(constant)								0.2850
F CES-D							0.4880	.0350
GestAge							.277	.202

[a] Dependent variable: Father's Affiliative Behavior.
[b] Predictors: (constant), Father's depressive symptoms score.
[c] Predictors: (constant), Father's depressive symptoms score, Gestational Age.
[*] Based on 5000 bootstrap samples.

[41,91], which is indicative of an orienting response [92]. On the whole, our findings suggest the opportunity, in line with both a family-centered care approach [93] and attachment theory [94], to encourage more fathers to be involved in their infants' care.

We note that there is a theoretical debate between calming cycle theory [30,33], which prioritizes maternal care of preterm infants, and an attachment theory view, which emphasizes that both father's care and mother's care, and consequent influences on infant outcomes, are important, different, and complementary [95,96], and. In order to test these two theoretical positions, based on two different learning mechanisms [26,97], future studies on fathers involved in preterm infant care should carefully monitor the progress of both parents in order to determine how emotionally connecting the father to the preterm infant affects maternal care and/or infant outcomes. However, we are not suggesting that the father could in any way replace the role of the mother.

With regard to our second hypothesis, the results confirm that paternal depressive symptoms are a main predictor of paternal Affiliative Behavior, but in the opposite direction of the one we had assumed. The results show that higher levels of paternal depressive symptoms predict higher levels of paternal Affiliative Behavior, instead of dampening this affectionate multimodal behavior, as we had expected. It is possible that fathers' depressive symptoms are related to an urgent need to find reassuring evidence of their infants' healthy and normal functioning. These fathers might then stimulate their infants with multiple channels of communication, perhaps in order to activate them. Although Affiliative Behavior is positive *per sé*, our interpretation is consistent with the literature on mothers of very preterm infants, documenting that these mothers show more active and direct/intrusive interactive behaviors, particularly in vocal and gazing behaviors, than mothers of term infants [98,99]. However, our interpretation requires further investigation in larger study populations.

The findings also revealed that the infant's older gestational age contributed to increased paternal Affiliative Behavior. This confirms our hypothesis, based on earlier findings, that the baby's physical appearance affects paternal behavior. That is, interacting with an infant who has a bigger body size is easier, and it reduces concerns about harming the infant. Our finding also suggests that with a larger sample size, the model including infant GA as a predictor along with paternal depressive symptoms could offer a more robust explanation.

One important limitation of the study is the small sample size of 20 father–infant dyads that were observed. There might be additional types of interactive coordination that we did not see because of sampling issues. Another limitation, particularly given the small sample size, is the large variation in the age of the infants when they were videotaped, due to the difficulties in recruiting parents in a stressful situation. Therefore, future research should enlarge the sample size to deepen the investigation of father–preterm infant interaction in the NICU. In addition, our promising results suggest the importance of involving fathers in studies of very preterm infant development, and the importance of using longitudinal designs starting from the NICU period.

4. Conclusion

The present study makes a unique contribution to the scant literature on paternal engagement and early interactions with preterm infants during the stay in the NICU. Our findings show the presence of bidirectional sequential patterns of communication between fathers and preterm infants at 35 weeks PMA, and provide important information about the quality and modalities of paternal communication.

In summary, we found that paternal affectionate multi-modal stimulation that specifically includes the father's voice plays a central role in evoking the infant's open-eyes and gaze toward the father; and reciprocally, that the infant alert state with open-eyes oriented toward the father increases the likelihood of paternal affectionate multi-modal communication. This picture might represent the earliest pattern of mutual attention between fathers and preterm infants.

On the whole, our findings also show that fathers are able to establish a positive interaction with their preterm infants, and that fathers may be profitably involved in preterm infant care in the NICU. This is very important, because it may be highly supportive to the cultural transition to family-centered care in NICUs. Thus, our findings suggest that it is important to create father-specific interventions designed to improve and sustain fathers' positive engagement. This intervention may improve paternal self-esteem and attachment feelings, increase early father-preterm infant face-to-face communication, and increase the fathers' confidence in their own ability to provide beneficial care for their babies. Such an intervention should inform fathers about the specific importance of the paternal voice and its potentially beneficial effects on preterm infants.

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CRediT authorship contribution statement

Alberto Stefana: Conceptualization, Data curation, Investigation, Methodology, Project administration, Resources, Writing - original draft, Writing - review & editing. **Manuela Lavelli**: Conceptualization, Formal analysis, Methodology, Resources, Supervision, Writing - review & editing. **Germano Rossi**: Formal analysis. **Beatrice Beebe**: Methodology, Writing - review & editing.

Declaration of competing interest

The authors declare that there is no conflict of interest.

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