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**Preterm Mother-Infant Interaction:
Speaking and Humming during
Kangaroo Care**

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Trabalho realizado sob a orientação da

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STATEMENT OF INTEGRITY

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Braga, October 16, 2023



(Fernanda Lisboa Guimarães)

Preterm Mother-Infant Interaction: Speaking and Humming during Kangaroo Care

Abstract

The quality of mother-infant interaction is crucial for the child's development. These interactions with preterm infants are even more challenging. Maternal vocalizations in the hospital setting seem to have positive effects for both mother and infant. This study aimed to analyze the differences in the quality of preterm mother-infant interaction during maternal speaking and maternal humming while the preterm infant is held in supported diagonal flexion (SDF) position of kangaroo care, and to evaluate these differences according to the infant's gestational age at birth, intrauterine and extrauterine age and sex. Forty mother-infant dyads (mother's age: 21-48 years) and their preterm infants (gestational age: 25-34 weeks), recruited at the Neonatal Intermediate Care Unit of a Lisbon Hospital, were evaluated using the Portuguese version of the Interaction Rating Scales. Maternal speaking and humming reveal different characteristics and purposes in mother-infant interaction and mother and infant can adjust depending on whether the interaction is spoken or hummed. The greater infant's gestational and intra and extrauterine age, as well as male sex, appear to be favorable factors for interaction. The results show the importance of disseminating this knowledge to guide neonatal care practices, leading to better infant development.

Keywords: preterm infants; mother-infant interaction; maternal speaking; maternal humming

Interação Mãe-Bebé Pré-termos: Fala e *Humming* Materno durante o Contacto Pele-a-Pele

Resumo

A qualidade da interação mãe-bebê é crucial para o desenvolvimento da criança. Com bebês pré-termos, essa interação é mais desafiadora. Vocalizações maternas no contexto hospitalar têm revelado efeitos positivos para a mãe e para o bebê. Este estudo teve como objetivo analisar as diferenças na qualidade da interação mãe-bebê pré-termos, durante a fala e o *humming* materno, com o bebê em posicionamento de flexão diagonal com suporte em canguru, e analisar essas diferenças de acordo com a idade gestacional ao nascimento, a idade cronológica e o sexo do bebê. Foram avaliadas quarenta díades de mães (21 – 48 anos) e seus bebês pré-termos (25 – 34 semanas de idade gestacional), recrutados na Unidade de Cuidados Intermediários Neonatais de um Hospital de Lisboa, através da versão portuguesa das *Interaction Rating Scales*. A fala e o humming materno revelam diferentes características e propósitos na interação mãe-bebê e a mãe e o bebê ajustam-se conforme a interação é falada ou cantada. As maiores idades gestacional e intra e extrauterina, assim como o sexo masculino, parecem ser fatores favoráveis para a interação. Os resultados mostram a importância da divulgação desse conhecimento para a orientação de práticas de cuidados neonatais, promovendo um melhor desenvolvimento do bebê.

Palavras-Chave: bebês pré-termos; interação mãe-bebê; fala materna; canto materno

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Preterm Mother-infant Interaction: Speaking and Humming during Kangaroo Care

Prematurity

According to the World Health Organization, a premature or preterm infant who is born before 37 weeks of gestation. Preterm newborns may be classified as mildly premature (32 to 37 weeks of gestation), very premature (28 to 32 weeks of gestation) or extremely premature (<28 weeks of gestation) (World Health Organization, 2023).

Prematurity is an urgent and growing public health problem. It is the leading cause of death among children under the age of five years (World Health Organization, 2022). About 11% of all children in the world are premature, accounting for 15 million preterm births per year (Chawanpaiboon et al., 2019; World Health Organization, 2022). In Portugal, 7.8% of all births are preterm, that is, one in every 13 infants is premature (Elias et al., 2023).

Preterm births are recognized as a physiologically traumatic experience for the newborn and a stressful and emotionally demanding challenge for parents (Gondwe & Holditch-Davis, 2015; Jiang et al., 2014; Loewenstein, 2018). After birth, preterm infants are separated from their mothers and often admitted to the Neonatal Intensive Care Unit (NICU), facing the challenge of adapting to the hostile environment of the incubator. Preterm infants are also deprived of biological sensory stimuli appropriate for their development, such as the frequencies of their mother's voice and heartbeat (Butler et al., 2014; Lickliter, 2000), and exposed to sound stimuli that are inappropriate for their level of sensory maturation (Cruz et al., 2015; Linhares et al., 2003). This exposure to the NICU environment and invasive procedures may be harmful to their neurodevelopment and neuronal maturation (McMahon et al., 2012; Wachman & Lahav, 2010).

Preterm mother-infant interaction

According to the Theory of Innate Intersubjectivity (Trevarthen, 1993), newborns are capable of picking up on another person's intentions and engaging in reciprocal and contingent exchanges. The theory of communicative musicality (Malloch & Trevarthen, 2009) assumes that these reciprocal exchanges are defined by musical parameters present in both infant-directed speaking and infant-directed humming. The infant's skills and behaviors at birth, such as crying, sucking and smiling, lead the mother to respond, which enable emotional activation between the dyad. Infants use interactive patterns, such as specific body movements, in response to maternal behaviors, displaying a highly organized conduct, characterized by reciprocity (Condon, 1977; Condon & Sander, 1974; Figueiredo, 1996). The quality of interactions, which affect the emotional, social and cognitive development of a child, should, therefore, be satisfactory (Bowlby, 2002; Winnicott, 1999).

Bodily, visual, vocal and facial expressions during mother-infant interactions are fundamental to an infant's development (Scortegagna et al., 2005). Interactions in early childhood, in particular, directly affect the brain circuitry, interfering with the emotional and intellectual development of an infant (Fox et al., 2010). The separation of preterm infants from their mothers limits infants' signals and their mothers' touches, vocalizations and gazes (Forcada-Guex et al., 2006b; Korja et al., 2012), which makes mother-infant interactions more difficult (Lickliter, 2000). The interaction between preterm dyads may also be compromised by the emotional vulnerability of mothers and the neurological immaturity of their infants, which may affect their self-regulation (Baylis et al., 2014; Jiang et al., 2014; Palazzi et al., 2020).

In line, studies have shown that the quality of the mother-baby relationship can contribute, as a moderating factor, to mitigating the possible effects of preterm birth for the child (Forcada-Guex et al., 2006) and for the mother-infant dyad relationship itself (Bozzette, 2007).

Maternal speaking and humming

Despite the neurological vulnerability of preterm infants, there is evidence that they process temporal aspects of the maternal voice (Carvalho et al., 2019). Preterm infants are able to differentiate between their mother's voice and the voice of another mother, and they show a preference for their mother's voice (Filippa, 2017).

The maternal voice calms down their preterm infants and draws their attention to a more active mother-infant interaction (Damiani & Piccinini, 2022). Exposure to live maternal speaking and humming fosters beneficial effects and increases the prevalence of a quiet alertness in preterm infants. Maternal speaking seems to be associated with this quiet alert state, while humming seems to be associated with an active sleeping state (Filippa et al., 2013). Maternal infant-directed speaking and humming affect a preterm infant's physiological and behavioral responses (Damiani & Piccinini, 2022; Filippa et al., 2017), but studies in the literature point out that these two activities may have different purposes (Damiani & Piccinini, 2022; Trehub et al., 2015). Preterm infants are able to discriminate when their mothers speak to them or hum to them, responding differently in each case (Carvalho et al., 2019).

Recent studies have reported that maternal singing, more than speech, improves the infant's vagal activity (Filippa et al., 2022) and maternal humming provides greater synchrony, with more overlapping vocalizations, when compared to speech (Carvalho et al., 2019). Maternal infant-directed humming in a contingent way has been shown to improve an infant's self-regulation, moderating their state of arousal and reducing maternal anxiety (Corbeil et al., 2015; Haslbeck, 2013; Shoemark, 2019). These benefits may contribute to a better quality of mother-infant interaction under vulnerable conditions (Shoemark et al., 2021).

Maternal humming makes preterm infants smile more (Filippa et al., 2020) and appears to be more effective than speaking (Longhi, 2009) during mother-infant interactions. Infants born at six months of gestation remain attentive, maintain eye contact and reduce movements for longer during infant-directed humming than while their mothers are speaking (Nakata & Trehub, 2004).

Interactions with term infants are somehow different. During humming, mothers smile more and have more vivid facial expressions than when speaking directly to their full-term infants (Nakata & Trehub, 2004). In addition, mothers smile more when humming than when speaking to their term infants (Trehub et al., 2015).

The literature shows that maternal vocalizations establish a better connection between mothers and their preterm infants. However, there are few studies addressing the different characteristics of preterm mother-infant interaction during speaking and humming.

Objectives

This study aimed to analyze the differences in the quality of mother-infant interaction during speaking and humming (defined as singing some invented tune without words) to preterm infants (25-34 weeks of gestation) during kangaroo care using the supported diagonal flexion (SDF) positioning (1), and to analyze the differences in preterm mother-infant interactions during speaking and humming, according to the infant's gestational age at birth, intra and extrauterine age and sex (2).

Methodology

Procedure

Data were collected face-to-face in a hospital setting. Before that, the participants received information about the study, confidentiality issues were explained, and they received and signed an informed consent form.

A video recording was made of each of the dyads in the NICU during skin-to-skin contact, with the infants held in the SDF position. This kangaroo care position was chosen because it optimizes the dyad's visual contact and favors face-to-face exchanges between mother and infant, promoting better interactions.

Kangaroo care has been shown to be highly beneficial in neonatal intensive care (Feldman & Eidelman, 2007b; Feldman et al., 2002). Newborns are kept in an upright position in skin-to-skin contact with their mothers. This provides benefits to both the preterm infant and the mother, as kangaroo care strengthens the mother-infant bond, reduces maternal feelings of anxiety and depression, prevents hospital-acquired infections, stabilizes certain signs in the newborn, improves the infant's sleep and

contributes to healthy growth and development (Souza et al., 2022). Mothers who used the SDF position of kangaroo care (Buil et al., 2016) had greater sensitivity to the signals emitted by the infants, as well as more smiles, eye contact and contingent vocalizations (Buil et al., 2020).

The protocol lasted 15 minutes, with a sequence of 5 periods of 3 minutes each. Initially, the preterm infant was in a state of quiet alertness or drowsiness, and the mother was asked to remain silent for 3 minutes. Then, each mother was asked to speak (as usual, in the most natural possible way) or hum (an invented song, without using words) to the infant for the next 3 minutes, when she was interrupted and asked to remain silent. After the 3 minutes of silence, the mother was asked to speak or hum to the infant again, alternating with the previous speaking or humming, for 3 more minutes. At the end, another 3 minutes of silence was requested. That is, the mother spent 3 minutes in silence, 3 minutes speaking or humming, 3 minutes in silence, 3 minutes speaking or humming, and then 3 minutes in silence.

Mother-infant interaction was assessed by watching the video recordings. Three researchers coded interactions independently, using the mother-infant face-to-face interaction scale (IRSff) of the Interaction Rating Scales (IRS; Field, 1980), adapted to Portuguese by Figueiredo & Dias (2013).

Participants

The sample for this study was taken from a larger study (Carvalho, 2015) entitled "*A voz materna na condição de método canguru vs. condição de incubadora: análise dos parâmetros acústicos vocais, dos parâmetros vitais neonatais e da relação contingente de díades pré-termo*" carried out by the lead researcher Eduarda Salgado Carvalho, promoted by CESEM-NOVA-FCSH and validated by the CHULC Ethics Committee (Process no. 267/2015). The data was collected in the NICU of a public hospital.

Inclusion criteria for mothers were: age over 19 years, good comprehension and fluency in Portuguese, no hearing or vocalization difficulties and no addictive and/or psychiatric behaviors. The newborns included had no hearing difficulties, an intrauterine and extrauterine age of 32 and 37 weeks at the time of observation, stable vital parameters, no intraventricular hemorrhages, no congenital or neurological anomalies of the auditory cortex, and no use of a nasogastric tube or respiratory support. Dyads were excluded if the kangaroo method had not been practiced at least once.

Forty mothers and preterm infants took part in this study. Most mothers were Portuguese, and the rest had lived in Portugal for at least 7 years. Mothers' ages ranged from 21 to 48. Most infants were male. The average gestational age was 30 weeks and 2 days (25-34 weeks) at birth and 34 weeks and 2 days at the time of observation. The rest of the information about the sample is in Table 1.

Table 1*Sociodemographic data of mothers and infants*

	n	%	M	Range
Mothers				
Age (years)			34.10	21-48
Education (years)			15.35	6-24
Primary Education	2	5.0		
Secondary Education	9	22.5		
University Education	29	72.5		
Nationality				
Portuguese	28	70.0		
African/Brazilian	12	30.0		
Infants				
Sex				
Female	18	45.0		
Male	22	55.0		
Prematurity (weeks)				
<28	9	22.5		
28-32	24	60.0		
>32	7	17.5		
Chronological age			28	4-89
Gestational age at birth			212	173-241
Intrauterine and extrauterine age			240	224-262
Weight at birth (g)			1267	590-2165
<1000	8	20.0		
1000-1499	24	60.0		
1500-2499	8	20.0		
Weight at observation (g)			1558	1060-2185

Note. N = 40

Instruments

Interaction Rating Scales (IRS; Field, 1980; Portuguese version by Figueiredo, 2023)

This study used the face-to-face Interaction Rating Scale (IRSff), a mother-infant interaction rating scale made up of 20 items, 10 evaluating the mothers' behaviors and 10, the infants' behavior. Videos of the interactions were used for the assessments. The dimensions assessed for the infants during the interaction were: status (from sleepy to alert), meaningful physical activity, atypical physical activity, head orientation, eye contact, gaze aversion, facial expressions, positive vocalizations, negative vocalizations and play behavior. The dimensions analyzed for the mothers were: status (from anxious/depressed to attentive/alert), meaningful physical activity, head orientation, eye contact, facial expressions, meaningful vocalizations, silence, contingent response, infantilized behaviors and play behaviors. Each item was scored from 1 to 3 according to the behavior displayed by the mother and the infant. The final result was the sum of the scores for each item divided by the number of items on the scale. Higher total scores indicated a better quality of mother-infant interaction (Figueiredo & Dias, 2013).

For the evaluation of eye contact in the infant scale, gaze maintenance was not taken into account, and an eye contact was counted every time the infant looked at the mother's eyes. Play behavior was not included because the infants were too small to make this assessment. Therefore, this item was removed from the study and from the statistical analyses, both in the mother's and the infant's assessment.

The Portuguese version has high internal consistency, with a Cronbach's alpha of 0.85 for infants, 0.91 for mothers, test-retest reliability, and concurrent and predictive validity (Figueiredo & Dias, 2013). The weighted kappa coefficient was used to check inter-rater agreement. According to Altman (1991), kappa values equal to or above 0.61 indicate good agreement. The percentage of agreement in mothers ranged from 55% to 100% and in infants from 70% to 100%, with overall good agreement between the three raters. Only 5 items scored lower: the mothers' status and eye contact in speaking, the mothers' status and facial expression in humming and the infants' negative vocalizations in speaking. Kappa statistics for some items (n=5) could not be calculated due to at least one of the researchers having constant values. The items not calculated were the mothers' silence in maternal speaking and humming, the infants' gaze aversion in speaking and the infants' head orientation and gaze aversion in humming.

Data analyses

Data analysis was carried out using IBM® SPSS® Statistics (version 28.0). Data were described using absolute and relative frequencies for categorical variables and means and standard deviations for continuous variables.

The Bonferroni-corrected generalized estimating equations (GEE) model for the adjustment of multiple comparisons was used to analyze the differences in the quality of mother-infant interaction during speaking and humming (objective 1) and to analyze the differences in the quality of mother-infant interaction during maternal speaking and maternal humming according to the infant's gestational age at birth, intrauterine and extrauterine age and sex (objective 2). This analysis compared groups during both speaking and humming simultaneously to control for type I errors. Significance was set at $p < 0.05$ for all analyses.

Results

Differences between maternal speaking and humming in mother-infant interactions

There were no significant differences in the mothers' interactional behaviors ($p = .676$) when speaking or humming. However, the mothers were significantly ($p = .005$) more attentive and alert when speaking ($M = 1.90$; $SD = .74$) than when humming ($M = 1.64$; $SD = .55$); they showed significantly ($p = .035$) more meaningful vocalizations while humming ($M = 2.54$, $SD = .51$) than when speaking ($M = 2.33$, $SD = .60$); and significantly ($p = .014$) more infantilized behaviors while speaking ($M = 2.17$, $SD = .56$) than when humming ($M = 1.93$, $SD = .39$).

In contrast, infants had significantly ($p = .025$) more interactional behaviors during maternal speaking ($M = 2.51$, $SD = .21$) than humming ($M = 2.43$, $SD = .18$). They also showed significantly ($p = .001$) more alert behaviors ($M = 2.37$, $SD = .55$), significantly ($p = .007$) less atypical physical activity ($M = 2.82$, $SD = .43$) and significantly ($p = .022$) more eye contact ($M = 2.20$, $SD = .52$) during maternal speaking than humming ($M = 2.11$, $SD = .50$; $M = 2.59$, $SD = .61$; and $M = 2.02$, $SD = .55$). However, they showed significantly ($p = .048$) less gaze aversion during maternal humming ($M = 2.82$, $SD = .42$) than speaking ($M = 2.69$, $SD = .50$).

Table 2

Differences between maternal speaking and humming in mother-infant interactions

	Speaking		Humming		95% CI		<i>p</i>
	M	SD	M	SD	LL	UL	
Mothers							
Interactional behavior	2.26	.29	2.24	.22	-.05	.08	.676
Status	1.90	.74	1.64	.55	.08	.42	.005*
Meaningful physical activity	1.87	.60	1.78	.51	.08	.27	.309

Head orientation	2.89	.40	2.99	.05	-.22	.02	.116
Eye contact	1.74	.75	1.71	.82	-.20	.27	.779
Facial expression	2.02	.26	2.07	.30	-.15	.05	.315
Meaningful vocalizations	2.33	.60	2.54	.51	-.40	-.01	.035*
Silence	3.00	.00	2.99	.05	-.01	.02	.311
Contingent response	2.41	.57	2.53	.57	-.31	.06	.189
Infantilized behavior	2.17	.56	1.93	.39	.05	.42	.014*
Infants							
Interactional behavior	2.51	.21	2.43	.18	.01	.13	.025*
Status	2.37	.55	2.11	.50	.10	.40	.001*
Meaningful physical activity	2.38	.69	2.44	.49	-.25	.13	.542
Atypical physical activity	2.82	.43	2.59	.61	.06	.40	.007*
Head orientation	2.96	.22	2.88	.40	-.05	.21	.210
Eye contact	2.20	.52	2.02	.55	.03	.34	.022*
Gaze aversion	2.69	.50	2.82	.42	-.26	-.00	.048*
Facial expression	3.00	.00	2.99	.05	-.01	.02	.311
Positive vocalization	1.31	.47	1.22	.46	-.05	.23	.205
Negative vocalization	2.85	.38	2.87	.38	-.12	.09	.746

Note. CI = Confidence interval; LL = Lower limit; UL = Upper limit; * $p < .05$

Differences in mother-infant interactions according to the infant's gestational age

The comparisons of groups according to gestational age did not reveal any significant differences ($p = .433$) in mothers' interactional behavior when they were speaking or humming to their infants. Mothers whose infants were older than 214 days gestational age at birth showed a more alert and attentive posture in relation to their infants while speaking ($M = 2.42$, $SD = .58$) than humming ($M = 2.08$, $SD = .49$).

Infants over 214 days gestational age were also significantly ($p = .042$) more alert during maternal speaking ($M = 1.97$, $SD = .76$) than humming ($M = 1.70$, $SD = .52$). Infants at a gestational age of 214 days or less showed a significantly ($p = .043$) higher mean value of atypical physical activity during humming ($M = 2.85$, $SD = .46$) than speaking ($M = 2.60$, $SD = .58$).

Table 3*Differences in mother-infant interactions according to the infant's gestational age at birth*

	Speaking		Humming		<i>p</i>
	≤ 214 days	>214 days	≤ 214 days	>214 days	
	M ± SD	M ± SD	M ± SD	M ± SD	
Mothers					
Interactional behavior	2.51 ± .31	2.52 ± .31	2.41 ± .29	2.49 ± .21	.433
Status	2.32 ± .54 ^{ab}	2.42 ± .58 ^b	2.15 ± .51 ^{ab}	2.08 ± .49 ^a	.008*
Meaningful physical activity	2.45 ± .68	2.32 ± .71	2.32 ± .51	2.57 ± .43	.090
Head orientation	2.85 ± .33	2.80 ± .52	2.63 ± .58	2.55 ± .66	.052
Eye contact	2.98 ± .07	2.93 ± .30	2.78 ± .55	2.97 ± .10	.289
Facial expression	2.11 ± .52	2.28 ± .52	1.95 ± .54	2.08 ± .57	.090
Meaningful vocalizations	2.25 ± .65	2.42 ± .55	2.55 ± .50	2.53 ± .53	.170
Silence	3.00 ± .00	3.00 ± .00	2.98 ± .07	3.00 ± .00	.305
Contingent response	2.47 ± .63	2.35 ± .50	2.47 ± .57	2.60 ± .58	.452
Infantilized behavior	2.17 ± .64	2.17 ± .50	1.88 ± .52	1.98 ± .20	.104
Infants					
Interactional behavior	2.17 ± .21	2.34 ± .25	2.19 ± .20	2.27 ± .22	.138
Status	1.82 ± .73 ^{ab}	1.97 ± .76 ^b	1.58 ± .59 ^{ab}	1.70 ± .52 ^a	.042*
Meaningful physical activity	1.72 ± .39	2.03 ± .72	1.68 ± .58	1.88 ± .44	.327
Atypical physical activity	2.60 ± .58 ^a	2.78 ± .41 ^{ab}	2.85 ± .46 ^b	2.80± .38 ^{ab}	.043*
Head orientation	2.85 ± .50	2.93 ± .30	3.00 ± .00	2.98 ± .07	.241
Eye contact	1.50 ± .67	1.98 ± .77	1.62 ± .78	1.80 ± .88	.171
Gaze aversion	3.00 ± .00	3.00 ± .00	3.00 ± .00	2.98 ± .07	.305
Facial expression	1.98 ± .30	2.07 ± .23	2.02 ± .28	2.13 ± .31	.433
Positive vocalization	1.30 ± .43	1.32 ± .51	1.17 ± .37	1.27 ± .55	.552
Negative vocalization	2.77 ± .45	2.93 ± .30	2.82 ± .49	2.92 ± .24	.441

Note. ^{a,b} Equal letters indicate no significant differences (Bonferroni test, $p < .05$); * $p < .05$

Differences in mother-infant interactions according to the infant's intra and extrauterine age

The analysis of the interactions between maternal speaking and humming according to the intra and extrauterine age of the infants revealed that mothers of infants at an intra and extrauterine age of 239 days or less showed significantly ($M = 1.88$, $SD = .44$) less active and alert behaviors when humming ($p < .001$) than in the other intra and extrauterine age groups ($M = 2.25$, $SD = .61$; $M = 2.48$, $SD = .48$; and $M = 2.35$, $SD = .45$).

Additionally, mothers of infants in the same group (intra and extrauterine age: ≤ 239 days) showed significantly ($p = .013$) fewer deviations of head orientation while speaking ($M = 2.85$, $SD = .33$) than when humming ($M = 2.55$, $SD = .54$). Mothers of infants over 239 days of intra and extrauterine age showed significantly ($p = .002$) more facial expressions when speaking ($M = 2.40$, $SD = .44$) than mothers of infants at an intra and extrauterine age of 239 days or less while speaking ($M = 2.00$, $SD = .53$) and humming ($M = 1.83$, $SD = .55$).

Table 4 shows that infants at an intra and extrauterine age greater than 239 days were significantly ($p = .016$) more alert during maternal speaking ($M = 2.03$, $SD = .75$) than infants of both ages during maternal humming ($M = 1.57$, $SD = .47$) and speaking ($M = 1.72$, $SD = .62$). Moreover, infants over 239 days of intra and extrauterine age displayed significantly more physical activity during maternal speaking ($M = 2.12$, $SD = .58$) than infants aged 239 days or less during both maternal speaking ($M = 1.63$, $SD = .53$) and humming ($M = 1.65$, $SD = .48$), with a statistically significant difference ($p = .022$).

Table 4

Differences in mother-infant interactions according to the infant's intra and extrauterine age

	Speaking		Humming		<i>p</i>
	≤ 239 days	>239 days	≤ 239 days	>239 days	
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Mothers					
Interactional behavior	2.50 ± .27	2.53 ± .34	2.42 ± .20	2.48 ± .30	.297
Status	2.25 ± .61 ^b	2.48 ± .48 ^b	1.88 ± .44 ^a	2.35 ± .45 ^b	<.001*
Meaningful physical activity	2.40 ± .70	2.37 ± .70	2.50 ± .44	2.38 ± .53	.750
Head orientation	2.85 ± .33 ^b	2.80 ± .52 ^{ab}	2.55 ± .54 ^a	2.63 ± .69 ^{ab}	.013*
Eye contact	2.98 ± .07	2.93 ± .30	2.87 ± .37	2.88 ± .45	.217
Facial expression	2.00 ± .53 ^a	2.40 ± .44 ^b	1.83 ± .55 ^a	2.20 ± .51 ^{ab}	.002*
Meaningful vocalizations	2.40 ± .55	2.27 ± .65	2.52 ± .54	2.57 ± .50	.106

Silence	3.00 ± .00	3.00 ± .00	2.98 ± .07	3.00 ± .00	.305
Contingent response	2.43 ± .53	2.38 ± .61	2.62 ± .49	2.45 ± .64	.449
Infantilized behavior	2.20 ± .52	2.13 ± .62	2.03 ± .15	1.83 ± .52	.083
Infants					
Interactional behavior	2.23 ± .21	2.27 ± .27	2.21 ± .17	2.26 ± .25	.776
Status	1.75 ± .72 ^{ab}	2.03 ± .75 ^b	1.57 ± .47 ^a	1.72 ± .62 ^a	.016*
Meaningful physical activity	1.63 ± .53 ^a	2.12 ± .58 ^b	1.65 ± .48 ^a	1.92 ± .53 ^{ab}	.022*
Atypical physical activity	2.75 ± .42	2.63 ± .58	2.85 ± .33	2.80 ± .50	.226
Head orientation	3.00 ± .00	2.78 ± .55	2.98 ± .07	3.00 ± .00	.118
Eye contact	1.68 ± .75	1.80 ± .78	1.67 ± .83	1.75 ± .84	.960
Gaze aversion	3.00 ± .00	3.00 ± .00	2.98 ± .07	3.00 ± .00	.305
Facial expression	2.08 ± .28	1.97 ± .24	2.10 ± .24	2.05 ± .35	.134
Positive vocalization	1.25 ± .43	1.37 ± .51	1.13 ± .31	1.30 ± .57	.275
Negative vocalization	2.95 ± .16	2.75 ± .51	2.95 ± .12	2.78 ± .52	.346

Note. ^{a,b} Equal letters indicate no significant differences (Bonferroni test, $p < .05$); * $p < .05$

Differences in mother-infant interactions according to the infant's sex

The analysis of infants' sex during maternal speaking and humming revealed that mothers of male infants had significantly ($p = .018$) more interactional behaviours during maternal speaking ($M = 2.59$, $SD = .25$) than mothers of female infants during humming ($M = 2.38$, $SD = .20$). The results of maternal status revealed that mothers of male infants had significantly more alert behaviours ($p = .001$) during speaking ($M = 2.52$, $SD = .41$) than mothers of both female ($M = 2.06$, $SD = .60$) and male ($M = 2.17$, $SD = .41$) infants while humming. In addition, mothers of male infants had significantly fewer deviations of head orientation ($p = .018$) during maternal speaking ($M = 2.89$, $SD = .30$) than mothers of both female ($M = 2.52$, $SD = .70$) and male ($M = 2.65$, $SD = .55$) infants during humming. Finally, mothers of male infants had significantly ($p = .001$) more meaningful vocalizations ($M = 2.73$, $SD = .38$) during humming than mothers of female infants during both speaking ($M = 2.17$, $SD = .61$) and humming ($M = 2.31$, $SD = .57$).

The results of infant status revealed that, regardless of the infants' sex, mean values during speaking ($M = 1.86$, $SD = .66$; $M = 1.93$, $SD = .84$) were significantly ($p = .042$) higher than the means for infants during maternal humming ($M = 1.62$, $SD = .58$; $M = 1.67$, $SD = .52$). Male infants had significantly ($p = .002$) less atypical physical activity during maternal speaking ($M = 2.89$, $SD = .30$) and humming ($M = 2.95$, $SD = .16$) than female infants during maternal speaking ($M = 2.44$, $SD = .59$).

Finally, male infants had significantly ($p = .046$) fewer negative vocalizations during maternal humming ($M = 3.00$, $SD = .00$) than female infants during speaking ($M = 2.78$, $SD = .46$) and humming ($M = 2.70$, $SD = .53$).

Table 5

Differences in mother-infant interactions according to the infant's sex

	Speaking		Humming		<i>p</i>
	Male	Female	Male	Female	
	M ± SD	M ± SD	M ± SD	M ± SD	
Mothers					
Interactional behavior	2.59 ± .25 ^b	2.42 ± .35 ^{ab}	2.51 ± .28 ^{ab}	2.38 ± .20 ^a	.018*
Status	2.52 ± .41 ^b	2.19 ± .66 ^{ab}	2.17 ± .41 ^a	2.06 ± .60 ^a	.001*
Meaningful physical activity	2.52 ± .65	2.22 ± .72	2.53 ± .51	2.33 ± .44	.439
Head orientation	2.89 ± .30 ^b	2.74 ± .55 ^{ab}	2.65 ± .55 ^a	2.52 ± .70 ^a	.018*
Eye contact	3.00 ± .00	2.91 ± .32	2.85 ± .50	2.91 ± .25	.167
Facial expression	2.27 ± .48	2.11 ± .57	2.02 ± .50	2.02 ± .63	.083
Meaningful vocalizations	2.47 ± .57 ^{ab}	2.17 ± .61 ^a	2.73 ± .38 ^b	2.31 ± .57 ^a	.001*
Silence	3.00 ± .00	3.00 ± .00	2.98 ± .07	3.00 ± .00	.306
Contingent response	2.50 ± .53	2.30 ± .60	2.65 ± .56	2.39 ± .56	.216
Infantilized behavior	2.15 ± .59	2.19 ± .55	2.00 ± .41	1.85 ± .37	.083
Infants					
Interactional behavior	2.29 ± .22	2.20 ± .26	2.26 ± .22	2.20 ± .20	.538
Status	1.86 ± .66 ^b	1.93 ± .84 ^b	1.62 ± .58 ^a	1.67 ± .52 ^a	.042*
Meaningful physical activity	1.85 ± .58	1.91 ± .63	1.74 ± .46	1.83 ± .59	.716
Atypical physical activity	2.89 ± .30 ^b	2.44 ± .59 ^a	2.95 ± .16 ^b	2.67 ± .57 ^{ab}	.002*
Head orientation	2.91 ± .43	2.87 ± .38	3.00 ± .00	2.98 ± .08	.204
Eye contact	1.83 ± .70	1.63 ± .82	1.76 ± .90	1.65 ± .74	.823
Gaze aversion	3.00 ± .00	3.00 ± .00	3.00 ± .00	2.98 ± .08	.303
Facial expression	2.02 ± .13	2.04 ± .38	2.09 ± .23	2.06 ± .37	.597
Positive vocalization	1.38 ± .52	1.22 ± .40	1.17 ± .47	1.28 ± .46	.150
Negative vocalization	2.91 ± .31 ^{ab}	2.78 ± .46 ^a	3.00 ± .00 ^b	2.70 ± .53 ^a	.046*

Note. ^{a,b} Equal letters indicate no significant differences (Bonferroni test, $p < .05$); * $p < .05$

Discussion

The present study sought to analyze the characteristics of mother-infant interaction during maternal speaking and maternal humming, as well as the effects of the infant's gestational age at birth, intra and extrauterine age and sex, during maternal speaking and humming, on mother-infant interaction. the results show that speaking and humming have different effects on mother-infant interaction, and speaking is associated with a more alert behavior for both partners in the interaction. the infant's higher gestational age and the infant's higher intra and extrauterine age seem to optimize mother infant interaction during maternal speaking. It is also concluded that male sex seems to be a facilitating factor for mother-infant interaction.

Differences between speaking and humming

We first conclude that speaking and humming produce different effects on mother-infant interaction. Compared to maternal humming, maternal speaking was associated with a more active and alertness state for both partners during interactions. This finding is in line with those reported by some previous studies, which found that maternal speaking was associated with a state of quiet alertness and more motor activity, whereas humming kept the infant in a state of active sleep (Filippa et al., 2013; Arias & Peña, 2016).

Likewise, mothers had more infantilized behaviors - more simplified movements and imitations – while interacting with the infant, and infants had more eye responses to their mothers - both more eye contacts and aversions to the mother's gaze – during maternal speaking. This may be assigned to a greater activation of the infant during maternal speaking (Filippa et al., 2013). Also, both mothers and fathers change their vocal qualities depending on the infant's state of wakefulness or sleep (Saliba et al., 2020), and the vocal interaction is reciprocal and complementary between the dyad. Therefore, when the infant is in a more alert state, the mother has more infantilized behaviors and interactions with the infant, and the infant, in turn, makes more eye contact with the mother. Another study that included infants between 29 and 37 weeks of gestational age who were exposed to their mother's speaking and humming also found an increase in eye opening, with higher values during maternal speaking (Filippa et al., 2020). The higher prevalence of an active sleep state during humming may explain infants' lower gaze aversion responses to their mothers' eye contact (Filippa et al., 2013; Saliba et al., 2020). However, mothers produce a repetitive lullaby humming, and future studies should see whether these same behaviors are observed when the mothers sing in different styles, either (lullabies or play songs (songs sung in a playful, upbeat style).

Mothers produced fewer meaningful vocalizations during speaking than humming. Meaningful vocalizations are those appropriate to respond to an infant's vocalizations; they occur during turn-taking and give the infant a greater opportunity to alternate with their mother's vocalizations. During humming, however, vocal flow is less interrupted, and phrase duration and melodic contours are more repetitive, which constructs anticipation of the end of the phrases, prompting infants to produce overlapping vocalizations (Carvalho et al., 2019).

Infants, in turn, had a greater interactional behavior with the mother in speaking compared to humming, which might indicate that speaking is a more favorable condition for mother-infant interaction. However, this result could be explained by the fact that during speaking, as the infant is in a more alert state, there is a greater possibility of the infant having more interactive behaviors with the mother.

Atypical physical activities are strange motor movements, without clear interactive purposes, or which result from high malaise/self-regulation difficulties. In infants, they were observed less frequently during maternal speaking than humming, which was against expectations and a study with term infants that found that infant-directed humming was more effective than speaking in delaying the onset of infant crying and distress (Corbeil et al., 2015).

The differences found in dyad interaction during maternal speaking and humming may also be explained by the fact that mothers have more experience in speaking to infants than humming to them. The limited privacy and intimacy that mothers may have in the NICU may inhibit them more while humming than speaking.

Differences in mother-infant interaction according to the infant's gestational age

Less preterm dyads were more alert during the interaction, suggesting that higher gestational age can optimize mother-infant interaction during speaking.

The analysis of the effect of gestational age at birth revealed that mothers of less preterm infants (> 214 days gestational age) were more alert during maternal speaking than humming, in agreement with two studies (Filippa et al., 2013; Shellaas et al., 2019). The latter included preterm infants at ≥ 35 weeks gestational age and reported that maternal speaking was associated with a decrease in sleep and an increase in wakefulness. This might have been an effect of the age of preterm infants, as mothers seem to adapt to the expectations that they have of their infants. Mothers seem to expect more responsiveness and involvement from older infants and are more active than the mothers of younger infants, maybe because they see younger infants as more vulnerable and less competent for interactions. Less preterm infants were also more alert during maternal speaking than humming.

However, it was also found that lower gestational age at birth seems to contribute to lower atypical physical activity during humming. More preterm infants, born at 214 days gestational age or less, had less atypical physical activity during maternal humming than speaking, suggesting that humming, more than speaking, may favor self-regulation (Haslbeck, 2013) in more preterm infants, or that infants may be calmer because of the state of drowsiness that humming seems to induce (Filippa et al., 2013; Saliba et al., 2020).

Differences in mother-infant interaction according to the infant's intra and extrauterine age

Older dyads had greater alert behavior, infants show more meaningful physical activity, and mothers more facial expressions, which suggests that the infants' higher intra and extrauterine age seems to optimize the development of mother-infant interaction during maternal speaking.

Mothers of younger infants, whose intra and extrauterine age was ≤ 239 days, were more attentive and alert and had fewer deviations of head orientation during maternal speaking than humming. this may be associated with the fact that infants are at a greater state of alertness during maternal speaking (filippa 2013, sheellaas et al., 2019). however, a study with full-term infants found that humming fosters greater infant involvement, as they their attention increases and they maintain eye contact and reduce their movements, which contributes to greater emotional coordination with their mothers (nakata & trehub, 2004).

Mothers of older infants (intra and extrauterine age > 239 days) were more attentive and alert during both activities than mothers of younger infants during humming, which makes sense given that older infants are able to interact more with their mothers. Studies should be conducted to compare the age differences of preterm infants, but also to analyze how differences in maternal speaking and humming affect the mothers themselves. Mothers of older infants also showed more facial expressions while speaking than mothers of younger infants when speaking or humming. Again, this was expected, given that the older the infants, the greater their capacity to communicate and interact actively with their mothers. The immaturity of preterm infants may affect their perception and discrimination of auditory stimuli, which makes their responses to their mother's voice less robust than those of full-term infants (de Regnier et al., 2002). The use of more facial expressions during maternal speaking than humming should be expected, as humming seems to indicate a less active state than speaking (Filippa et al., 2013). However, humming may be more favorable for preterm infants with less intra and extrauterine age, since the results indicate that humming is associated with a less alert state when compared to speaking.

Older infants were more alert during maternal speaking than infants of both ages during humming, in line with the study mentioned above (Filippa et al., 2013). Another study found a reduction of the motor activity of full-term infants and more silence time during infant-directed humming (Arias & Peña, 2016).

During maternal speaking, older infants had more meaningful physical activity, that is, more physical activity focused on the interaction with their mothers, than younger infants during both maternal speaking and humming. This was expected because older infants have more possibilities to communicate and interact with their mothers.

Differences in mother-infant interaction according to the infant's sex

Mothers of male infants displayed more active interactional behaviors during speaking than mothers of female infants during humming. This goes against a study with preterm infants that found that engagement in humming was greater among mothers of female infants than among mothers of male infants (Carvalho et al., 2020). Mothers of male infants seem to be more alert and attentive during speaking, with fewer head movements away from their infants' head than mothers of infants of both sexes during maternal humming. Moreover, mothers of male infants produced more meaningful vocalizations during humming than mothers of female infants during speaking and humming.

Studies in the literature found greater synchronization during humming to female preterm infants than to male preterm infants. This underscores the greater synchronicity in mother-daughter dyads than in mother-son dyads (Feldman, 2003). The results show that male infants present less atypical physical activity, both in maternal speaking and humming, compared to female infants. They also present fewer negative vocalizations in humming. In all the items that display statistically significant differences, except for the infant's status, the dyads of male infants present higher scores. This suggests a more facilitative interaction between dyads with male infants. In this study, mother-son dyad interactions seemed to be more facilitating. Nevertheless, further studies should be conducted to better understand the effects of sex when mothers speak or hum to their infants.

Limitations and future implications

Regarding the limitations presented by this paper, the first is due to the small number of participants in this study, which did not allow us to control for certain variables that may be interfering with the quality of mother-infant interaction, such as the participants' context of origin. The verbal content of the mothers' speech was also not controlled in this study, neither was the type of mother's humming. These maternal speeches and humming improvisations vary from mother to mother and may also be influencing the results. Another limitation of this study concerns the instrument. The fact that the scale

used in this study is not adapted to premature infants prevents us from assessing some of the behavioral details of these infants.

As far as the implications are concerned, it would be pertinent to repeat the study controlling for the limitations mentioned above. Further studies could control the verbal content of the mothers' speaking and the mothers' type of humming. Preterm mother-infant interaction behaviors could also be analyzed using other mother-infant interaction scales, ideally scales specific to or adapted for preterm infants. Finally, the present study observed mothers humming in a lullaby style, and future studies could explore whether the behaviors found are similar when mothers use different musical styles (e.g., play songs).

Final Remarks

In an innovative way, this research has broadened our knowledge of how different vocal modalities, namely maternal speaking and humming, and different factors, such as gestational age, intra and extrauterine age and the infant's sex, affect the interaction of preterm mother-infant dyads.

Maternal speaking and humming present different purposes for interaction, and different characteristics of interaction were observed in these two conditions. Both mother and infant adjust according to whether the interaction is speaking or humming, which also shows that the infant is able to differentiate between these two situations. It has also been shown that maternal speaking seems to promote more active interaction, while humming seems to favor self-regulation in more preterm infants. In addition, the infants' higher gestational age and intra and extrauterine age, as well as male sex, appear to be favorable factors for the quality of mother-infant interaction.

Based on the findings reported here, there is a clear need for further studies to elucidate these preliminary results, in order to better understand the different purposes that speaking and humming have in interaction and the long-term impact that these interactions have on the infant's development. This knowledge should be disseminated in order to help parents and/or caregivers to interact more effectively with preterm infants in the future and to develop appropriate interventions adapted to the needs of preterm dyads, in order to mitigate the potential impacts caused by preterm birth.

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