sempre:
Society for Education, Music and Psychology Research

Article

Psychology of Music
1–15

DOI: 10.1177/03057356211073476
journals.sagepub.com/home/pom
SAGE

Melodic contours of maternal humming to preterm infants in kangaroo care and infants' overlapping vocalizations: A microanalytical study

Maria Eduarda Salgado Carvalho[1], João Manuel Rosado de Miranda Justo[2], Carolina Sá[3], Maya Gratier[4] and Helena Ferreira Rodrigues[5]

Abstract

Tonal or melodic contours of maternal voice directed to infants play a role in infants' self-regulation and vocal responsiveness. However, we are unaware about melodic contours of maternal humming directed to preterm infants and its role for infants' vocal responsiveness. We aimed (1) to identify the melodic contours (sinusoidal, bell-shaped, U-shaped, rising, falling, and linear contours) of maternal humming directed to preterm infants in kangaroo care and (2) to identify preterm infants' overlapping vocalizations in each humming melodic contour. Mothers ($N = 36$) were invited to speak and to hum (using an improvised melody) for their preterm infants during kangaroo care. A temporal segmentation (frequency and lengths) of melodic contours of humming, and descriptive comparative analyses were performed. We found a predominance of sinusoidal contours, followed by bell-shaped, rising, falling, U-shaped, and, finally, linear contours. Also a predominance of infants' overlapping vocalizations was found in sinusoidal and in bell-shaped contours. This study underlines the role of melodic contours of maternal humming to preterm infants, highlighting its communicative functions for the vocal engagement of preterm infants during kangaroo care.

Keywords

preterm infants, maternal humming, kangaroo care, melodic contours, infants' overlapping vocalizations

[1]CESEM-NOVA-FCSH, Lisboa, Portugal
[2]Universidade de Lisboa Faculdade de Psicologia, Lisboa, Portugal
[3]CESEM-NOVA-FCSH, Lisboa, Portugal
[4]Université Paris-Nanterre, Nanterre, Île-de-France, France
[5]CESEM-NOVA-FCSH, Lisboa, Portugal

Corresponding author:
Maria Eduarda Salgado Carvalho, Universidade Nova de Lisboa Faculdade de Ciências Sociais e Humanas, Campus de Campolide, 1069-061 Lisboa, Portugal.
Email: educarte@sapo.pt

Fetuses at term are able to discriminate between linguistic and musical stimuli such as ascending and descending melodies (Granier-Deferre, Ribeiro, et al., 2011) and these can induce an orientation response (with a profound cardiac reaction) from the newborn at 6 weeks after birth (Granier-Deferre, Bassereau, et al., 2011). Extensive prenatal exposure to a melody during the third gestational trimester induces neural representations of the newborn and these may last up to 4 months after birth (Partanen et al., 2013). One-day-old newborns present a brain hemispheric specialization for native and non-native language (Vannasing et al., 2016).

From birth when mothers start to interact vocally with their infants, three different alternatives of vocal communication are available: speech, singing, and humming (singing with a closed mouth). These vocal modalities are composed of musical elements which ensure the coordination and synchronization within the dyads (Malloch & Trevarthen, 2009). One of these musical elements is the tonal or melodic contour, which is defined as the quality of movement or the shape of a melodic segment, taking into account the successive pitches (fundamental frequencies) or notes within a certain musical segment (a vocal sequence of musical tones with interruptions that are shorter than a predefined level). These tonal or melodic contours play a crucial role in communicative intentionality of early interactions (Malloch & Trevarthen, 2009; Trevarthen, 1993). In addition, these melodic contours may be modulated in a contingent way encouraging the infants' vocal responsiveness (Falk, 2011; Fernald, 1989; Papousek, 1996; Papousek et al., 1991; Trainor, 1996; Trehub et al., 1984; Trehub & Trainor, 1998).

Contingent interaction is a key condition for the engagement of newborns (Pelaez et al., 2011), synchronizing (alternating or overlapping) their vocalizations with their partners' vocalizations (Rosenthal, 1982). Contingent interaction requires a reciprocal capacity from both partners to capture and return the other's message. The contingent interaction may be reduced or compromised in preterm dyads due to several factors among which the difficulty of emotional self-regulation of one or both partners is of utmost importance. Kangaroo care is a method currently used in Neonatal Intensive Care Units (NICUs) as a multimodal experience with positive effects to promote the contingent interaction and also the self-regulation of preterm infants (Fluharty et al., 2021). More benefits for the contingent interaction of preterm dyads were found when the preterm infant is positioned diagonally in skin-to-skin contact according to the "kangaroo supported diagonal flexion positioning" (Buil et al., 2016) protocol.

A microanalytical study with preterm dyads during the speech and humming conditions in kangaroo supported diagonal flexion positioning shows that humming increases the infants' overlapping vocalizations favoring the dyadic attunement while speech increases the infants' vocal responses during pauses between phrases (Carvalho et al., 2019). In addition, more preterm infants' overlapping vocalizations were found during the final note of the maternal humming phrases underlining an early capacity of preterm infants to anticipate the ending of maternal humming phrases (Carvalho et al., 2020). This suggests that humming connects the partners and plays an important role in mother–infant tuning (Carvalho et al., 2019). The use of maternal singing during kangaroo care in NICU leads to the autonomic stability of preterm infants and reduces maternal anxiety (Arnon et al., 2014), improving the auditory processing of speech sounds (measured by electroencephalogram) in preterm infants when at term age (Kostilainen et al., 2021).

Falk (2011) analyzed the tonal contours in infant-directed (ID) speech versus ID singing in the context of play versus soothing using a protocol based on Cordes (2005), Papousek (1996), and Katz et al. (1996). This protocol presented the following three parameters using the program *Praat* (Boersma & Weenink, 2001): (1) form, including linear, bell-shaped, U-shaped, and sinusoidal contours; (2) direction, including ascending, descending, and flat contours; (3) slope, including flat and steep. Although similar tonal characteristics and melodic contours have been observed in the context of play, some differences in melodic contours have been found in soothing contexts, with more sinusoidal contours in singing than in speech (Falk, 2011).

Melodic contours can have similar communicative functions in ID speech and ID singing. According to the literature (Cordes, 2005; Papousek, 1996; Unyk et al., 1992), the falling and bell-shaped contours allow a decrease in the infant's state of arousal, calming, and comforting the infant and also helping to conclude a communicative cycle. In contrast, the rising and U-shaped contours can be cheerful, stimulating, exciting, and even threatening, increasing the infant's arousal level, which can range from enjoyment to a feeling of threat or surprise. The sinusoidal contours can maintain the infant's attention, ensuring a moderate level of arousal while the linear contours allow the maintenance of a minimum level of arousal, keeping the infant calm and even in a state of drowsiness (Papousek et al., 1991). A similar classification of melodic contours for ID singing was proposed by Cordes (2005): (1) "Schwingtyp" (oscillating songs), whose melodic contours smoothly oscillate and were rated as very calming and tender; (2) "encomium," which have a wide pitch range as well as bell-shaped and smoothly falling contours (rated as cheerful and stimulating); and (3) "admonishing," characterized by the diversity of contour types, with many steeply falling contours (rated as stimulating, exciting, and even menacing).

ID singing plays a crucial role in the regulation of infants' arousal levels ranging from high levels of attention and pleasure to levels of calm and well-being (Shenfield et al., 2003). ID singing presents a higher pitch level (Trainor & Zacharias, 1998), inducing a slower tempo and a more expressive vocal tone (Trainor, 1996; Trainor et al., 1997; Trehub et al., 1997). When mothers sing to their infants, they adjust the pitch, the tonal amplitude, and other qualities of their voices (Trehub & Trainor, 1998). This singing style changes according to the infants' needs, adjusting or influencing the infants' behavioral state (Trehub & Trainor, 1998) suggesting that musical and acoustic features of ID singing are more pronounced when the infant is present than when absent; many of these acoustic modifications are likely to attract infants' attention (Trainor, 1996; Trainor et al., 1997). Also an increase of maternal pitch (using speech or singing condition) was found after a positive response of the preterm infant such as opening the eyes, gazing at the mother, or smiling (Filippa et al., 2018). This suggests that preterm infants' behavior can play an important role in the vocal modulation of the maternal voice.

Parents and adults use two types of singing (playsongs and lullabies) which are likely to communicate different emotional messages to respond to their infants' needs inducing a change in their behavioral states, either to increase arousal or to soothe the infant (Trehub et al., 1993a). Lullabies aim to calm, decreasing the arousal level, ensuring an intimate and warm environment and inducing the infant's sleep, while playsongs promote engagement and emotion (Trehub & Trainor, 1998). Regarding the melodic contours, playsongs are characterized by contours with interval jumps and contours of different types like linear, steeply falling, and abruptly ending bell-shaped contours (Cordes, 2005); lullabies are characterized by smoothly oscillating sinusoidal contours (originally considered as "Schwingtyp" by Cordes, 2005), as well as by descending linear and bell-shaped or flat contours where the pitch range tends to be smaller (Cordes, 2005; Papousek, 1996). These characteristics are identical for adults of different cultures and musical systems (Trehub et al., 1993a, 1993b) and they are able to recognize lullabies by their universal characteristics of many and repeated sinusoidal and falling contours (Unyk et al., 1992).

Early vocal contact within preterm dyads in the NICU has been shown to promote intuitive parenting and parental communicative musicality (Filippa et al., 2021). Although studies in the literature highlight the use of maternal singing more than maternal humming, this one seems to be a current condition used by mothers when they want to calm or put their newborn infants to sleep. Probably, the use of maternal humming directed to preterm infant, due of words absence, can be a more accessible and favorable condition for mothers in order to maintain a state of emotional self-regulation in the context of NICU. In this way, the creative music therapy model at the NICU emphasizes the particular use of improvised humming (in lullaby style) directed to the preterm infant in a contingent way—adjusting its musical parameters (repetition, tempo, rhythmic, and melodic pattern) to breathing movements and signals emitted by the preterm infant (Haslbeck & Bassler, 2018; Haslbeck et al., 2020). The use of the contingent maternal humming particularly during kangaroo care has been emphasized in the practice of music therapy in neonatal care centered on the family and on the individual neurodevelopment of preterm newborns (Haslbeck et al., 2020). This sustains a moderate state of arousal and improving self-regulation (Shoemark, 2011, 2018, 2019) with benefits for the infants' neurodevelopment as well as to the progress of attachment (Haslbeck & Bassler, 2018; Loewy, 2015; Shoemark, 2011, 2018, 2019) improving early mother–infant interaction and maternal self-efficacy (Shoemark et al., 2021).

The use of contingent singing or humming aims to achieve a crucial balance between stimulation and holding using musical attributes such as melody, registration, dynamics, tempo, timbre, attack, and silence. The following three stages of contingent singing have been described (Shoemark, 2011; Shoemark & Grocke, 2010): (1) The use of a semi-sung motif (the moment when the voice changes from speech to singing) and of a single-line melody (using musical elements—tempo, rhythm, pitch, and timbre) at the point of the infant's availability; (2) ongoing improvised song (melody) as the context for interplay (in a melodic line with an ABAB shape to promote familiarity and to activate engagement); and (3) modifying singing as the infant becomes less available. However, doubts remain about how the use of maternal singing (or humming) can be adjusted to the infant's signals and needs. More studies are needed to investigate the musical characteristics of contingent singing in order to maintain the infant's self-regulation. If the melodic contours in maternal ID humming can play a crucial role in the transmission and understanding of different messages, we believe that it is important to understand the relationship between the melodic contours of maternal humming and the preterm infant's vocal responsiveness. The aims of this study are as follows: (1) to characterize the melodic contour styles of maternal humming directed to preterm infants in skin-to-skin and visual contact and (2) to know more about the relationship between the melodic contours in humming and the infant's overlapping vocalizations.

Method

Study design

This is a study with preterm dyads carried out at NICU in Maternidade Dr Alfredo da Costa hospital after being approved by the Ethical Committee of the Central Lisbon Hospital Center (267/2015). All mothers gave written informed consent and were interviewed with a Sociodemographic and Clinical Questionnaire. Using video and audio recordings, each preterm dyad was observed in NICU during skin-to-skin contact according to the "kangaroo supported diagonal flexion positioning" (Buil et al., 2016) protocol in order to improve eye contact between mother and infant. In the baseline condition, preterm infants were in a state of quiet alertness or drowsiness (Brazelton & Nugent, 2011, pp. 49–51). Each observation took place in the skin-to-skin condition next to each incubator in the rooms of the intermediate care unit. During the observation time, the door was closed to avoid interference from external noise. Also, during observations, the monitoring alarms of the observed preterm infant were turned off. With very few cases in which the father was present, in addition to the preterm dyad, only the researcher and the hospital staff were present.

Although this study focuses on the melodic contours of maternal humming, data collected were based on a larger study about the vocal responsiveness of preterm infants in NICU when their mothers were invited to speak (as usually) and to sing in humming condition (an improvised melody with the mouth closed) for their infants during kangaroo care. Although some mothers resisted the invitation to sing, the explanation about humming was enough to resolve the situation; most of the mothers stated that humming like speaking was a part of their communication with their preterm infants. This protocol (counterbalanced across speech vs. humming conditions) was composed by the following sequence of five periods of 3 min each: (1) silent baseline, (2) maternal voice (speech or humming), (3) silence, (4) maternal voice (speech or humming), and (5) final silence. Data were coded with the aim of performing various microanalytical analyses of the temporal characteristics of maternal and preterm infants' vocalizations in order to know the infants' vocal responsiveness in both speech and humming conditions.

Exclusion criteria

During recruitment dyads were excluded based on the following criteria: (1) mother being younger than 19 years old, (2) difficulties understanding and speaking the Portuguese language, (3) infant or mother having an auditory deficit, (4) gestation without medical supervision, (5) previous psychiatric pathology or serious negative emotional states, and (6) addictive behaviors. Dyads were also excluded if, at the observation moment, infants had the following: (1) post-menstrual age less than 32 weeks or higher than 37 weeks, (2) instability of the vital parameters, (3) support of CIPAP (Continuous Positive Airway Pressure), (4) intraventricular hemorrhages, (5) congenital or neurological anomalies of the auditory cortex, (6) nasogastric tube, and (7) supported breathing. Dyads were also excluded if kangaroo care had not been practiced at least once.

Participants

Preterm dyads ($N = 50$) were recruited. Some mothers did not participate because of issues related to hospital routines or due to personal reasons ($n = 10$) while other participants were excluded due to disruption of the recording process ($n = 4$) like interruptions due to preterm infants' distress or staff activities. The final sample included 36 preterm dyads. Regarding maternal nationality, most of the mothers were Portuguese ($n = 26$, 72.22%) while the remaining ($n = 10$, 27.77%) were from African or Brazilian backgrounds living in Portugal for at least 7 years. Maternal age was in average 34 years old ($SD = 5.63$, min. = 21, max. = 48) with a high number of successfully completed years at school ($M = 15.33$, $SD = 3.69$, min. = 6, max. = 24), nearly two-thirds of the mothers were married ($n = 23$, 63.88%) and almost two-thirds of the mothers did not have other children ($n = 22$, 61.11%). There were no mothers with formal musical background.

In the sample of infants, there were more male ($n = 20$, 55.55%) than female infants ($n = 16$, 44.44%), gestational age at birth was 30 weeks and 4 days on average (gestational days at birth, $M = 212.78$, $SD = 17.11$, min. = 178, max. = 241), mean weight at birth was 1265.47 g

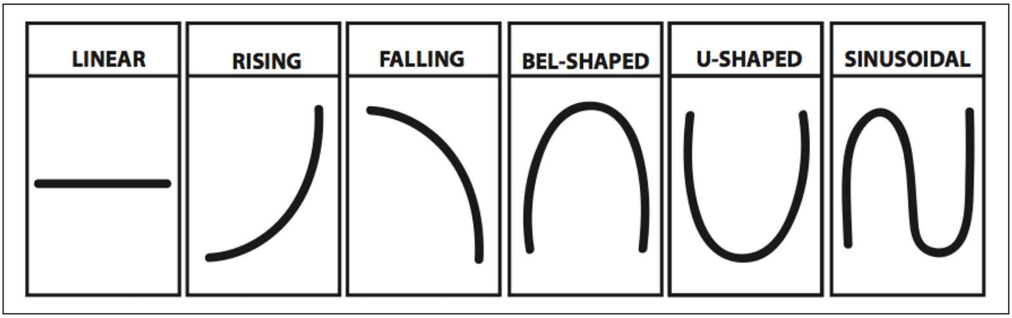

Figure 1. Melodic Contours.

(*SD* = 308.20, min. = 590 g, max. = 2,017 g), mean post-menstrual age at observation was 34 weeks and 1 day (days of mean post-menstrual age, *M* = 239.27, *SD* = 9.28, min. = 224, max. = 259), infants' chronological age at the time of observation was 26.5 days on average (*SD* = 19.99, min. = 4, max. = 81) and mean weigh at observation was 1,538.05 g (*SD* = 237.72, min. = 1,060 g, max. = 2,185 g).

Materials

Video recordings (MP4) and their corresponding audio recordings (WAV) were used to gather data from each dyad. To code the data, *ELAN* software (EUDICO Linguistic Annotator version 4.9.4) was used.

Coding of dyads' vocalizations

All maternal vocalizations were coded and quantified in terms of frequency (number of vocalizations per minute) and duration (milliseconds). In order to identify maternal vocalizations, we adopted the temporal criteria established by Gratier et al. (2015); each maternal vocalization was defined as the production of an audible vocal sound by the mother which interruption of sound could not exceed 300 ms. All infants' vocalizations were coded and quantified only for frequency (number). An infant's overlapping vocalization was identified as the production of an audible vocalization by the infant that was at least partially simultaneous with a maternal vocalization.

The first author listened to each vocalization and assigned it to one of the six possible melodic contours (linear, rising, falling, bell-shaped, U-shaped, or sinusoidal) which were based on the classification of the tonal contours developed by Falk (2011). A linear contour is identified when the humming vocalization is flat, the rising contour is characterized by an increase of the musical tones, the falling contour is characterized by a decrease of the musical tones, the bell-shaped contour is a sequence of an increase followed by a decrease, the U-shaped contour is a sequence of a decrease followed by an increase, and the sinusoidal contour is composed of a sequence of a bell-shaped and a U-shaped contours independently of its sequence. Figure 1 shows the graphic representation of these six melodic contours.

Statistical analyses

For the characterization of melodic contours of maternal humming, several descriptive statistical analyses were performed relative to frequency (number) and length of maternal vocalizations in each melodic contour. Having in account that mothers' vocalizations were different in terms of individual frequencies (number), individual proportions were estimated for each melodic contour. For infants' overlapping vocalizations in each maternal melodic contour, only frequencies (number) were calculated. Knowing that the absolute number of infants' overlapping vocalizations vary widely among individuals, we estimated the individual proportion of infants' overlapping vocalizations for each type of maternal melodic contour as a function of the individual total of infants' overlapping vocalizations. Based on these individual proportions, several comparative statistical analyses (Student's *t*) were performed to understand which melodic contours were more frequent among maternal vocalizations and also to know if the infant's overlapping vocalizations varied in agreement with maternal melodic contours. Finally, correlations between mothers' individual proportions of humming melodic contours and the individual proportions of infants' overlapping vocalizations in each melodic contour were also estimated.

Reliability

A coding process of the temporal units of maternal and infants' vocalizations was carried out by two independent researchers for 30% of the sample. Intraclass correlation coefficients (ICC) were used to assess differences between the researchers. A high agreement was found for the frequencies of temporal units of maternal humming vocalizations (ICC = .999, $p < .001$) and also for pauses in humming (ICC = .999, $p < .001$). A high agreement was also found for the frequency of infants' overlapping vocalizations in humming (ICC = .996, $p < .001$). Regarding melodic contours, an additional reliability analysis was performed by two researchers with a musical background who studied seven dyads (19.44% of the participating dyads), achieving a high degree of agreement in all melodic contours: (1) linear (ICC = .944, $p = .002$), (2) rising (ICC = .999, $p < .001$), (3) falling (ICC = .996, $p < .001$), (4) bell-shaped (ICC = .995, $p < .001$), (5) U-shaped (ICC = .933, $p = .002$), and (6) sinusoidal (ICC = .992, $p < .001$).

Results

Melodic contours of maternal humming

The total of maternal humming vocalizations ($N = 1761$) was coded according to melodic contour: (1) linear ($n = 70$, 3.97%), (2) rising ($n = 365$, 20.72%), (3) falling ($n = 274$, 15.55%), (4) bell-shaped ($n = 407$, 23.11%), (5) U-shaped ($n = 118$, 6.70%), and (6) sinusoidal ($n = 527$, 29.92%). After the estimation of individual proportions, we found a predominance of sinusoidal contours, followed by bell-shaped, rising, falling, U-shaped, and, finally, linear contours (Table 1). Table 2 presents the significant differences (Student's *t*) between the individual proportions of the various pairs of melodic contours. The individual proportion of linear contours is significantly lower than rising, falling, bell-shaped, and sinusoidal contours. The individual proportion of rising contours is significantly higher than U-shaped contours. The individual proportion of U-shaped contours is significantly lower than both bell-shaped and sinusoidal contours.

Table 3 displays the descriptive statistics for the length of melodic contours in maternal humming. According to the results, the longest contour is the sinusoidal one, followed by bell-shaped, falling, U-shaped, rising, and linear. The significant differences between the lengths of the melodic contours are presented pair by pair in Table 4. The linear contour is significantly shorter than all other contours. The sinusoidal contour is significantly longer than the rising, falling, and U-shaped contours. The bell-shaped contour is significantly longer than the U-shaped, rising, and falling contours.

Table 1. Descriptive Statistics of the Individual Proportions of Melodic Contours as a Function of the Individual Total of the Humming Vocalizations ($N = 36$).

Melodic contours	*M*	*SD*	min. to max.
Linear	3.88	6.82	0–31.15
Rising	18.64	17.82	0–59.68
Falling	14.85	17.03	0–84.48
Bell-shaped	23.52	18.36	0–92.31
U-shaped	6.56	8.84	0–36.17
Sinusoidal	32.51	26.05	0–100.00

Table 2. Significant Differences Between the Individual Proportions of the Six Melodic Contours.

Melodic contour differences	*t*	*df*	*p**<
Linear versus rising	–4.64	35	.001
Linear versus falling	–3.67	35	.002
Linear versus bell-shaped	–5.68	35	.001
Linear versus sinusoidal	–6.08	35	.001
Rising versus U-shaped	3.36	35	.003
Bell-shaped versus U-shaped	4.66	35	.001
U-shaped versus sinusoidal	–5.82	35	.001

*$p < .003$.

Table 3. Descriptive Statistics of the Melodic Contours' Length.

Melodic contour types	*M*	*SD*	min. to max.
Linear	407.41	591.22	0–2,100.00
Rising	1,398.85	914.57	0–3,280.00
Falling	1,855.07	1,043.97	0–4,445.00
Bell-shaped	2,972.88	892.83	0–4,516.00
U-shaped	1,632.98	1,553.05	0–5,163.33
Sinusoidal	3,322.66	1,401.64	0–5,158.88

Infants' overlapping vocalizations according to the type of melodic contour

The percentage of infants' overlapping vocalizations was estimated for each type of melodic contour as a function of the total of infants' overlapping vocalizations in the total sample of overlapping vocalizations ($n = 162$): (1) linear ($n = 0$), (2) rising ($n = 28$, 17.28%), (3) falling ($n = 29$, 17.90%), (4) bell-shaped ($n = 40$, 24.69%), (5) U-shaped ($n = 8$, 4.93%), and (6) sinusoidal ($n = 57$, 35.18%).

Also the individual proportions of infants' overlapping vocalizations in each melodic contour as a function of the total of individual infants' overlapping vocalizations were estimated. The descriptive statistics of these individual proportions are presented in Table 5. The results show a predominance of infants' overlapping vocalizations during the sinusoidal contours

Table 4. Significant Differences Between the Means of the Six Melodic Contours' Length.

Melodic contour differences	*t*	*df*	*p**<
Linear versus rising	−7.75	35	.001
Linear versus falling	−8.69	35	.001
Linear versus bell-shaped	−15.24	35	.001
Linear versus U-shaped	−5.39	35	.001
Linear versus sinusoidal	−12.47	35	.001
Rising versus bell-shaped	−8.49	35	.001
Rising versus sinusoidal	−6.73	35	.001
Falling versus bell-shaped	−6.03	35	.001
Falling versus sinusoidal	−5.39	35	.001
Bell-shaped versus U-shaped	4.40	35	.001
U-shaped versus sinusoidal	−6.48	35	.001

$^{*}p < .003$.

Table 5. Descriptive Statistics of the Individual Proportions of Infants' Overlapping Vocalizations in Each Melodic Contour as a Function of the Total of Individual Infants' Overlapping Vocalizations ($N = 36$).

Melodic contours	*M*	*SD*	min. to max.
Linear	–	–	–
Rising	17.83	27.74	0–100
Falling	13.43	21.94	0–71.43
Bell-shaped	27.86	34.34	0–100
U-shaped	2.57	9.66	0–41.18
Sinusoidal	38.31	39.67	0–100

Table 6. Significant Differences Between the Individual Proportions of Infants' Overlapping Vocalizations in Several Melodic Contours as a Function of the Total of Individual Infants' Overlapping Vocalizations.

Infants' overlapping vocalizations in	*t*	*df*	*p**<
Bell-shaped versus U-shaped	3.83	28	.002
U-shaped versus sinusoidal	−4.67	28	.001

$^{*}p < .003$.

followed by the bell-shaped, rising, falling, and U-shaped contours. Infants' overlapping vocalizations were not found in the linear contours. Table 6 presents the significant differences between the various pairs of individual proportions as a function of the total of individual infants' overlapping vocalizations. According to the results, the individual proportion of infants' overlapping vocalizations during U-shaped is significantly lower than the individual proportion of infants' overlapping vocalizations during the sinusoidal contours as well as during the bell-shaped contours. Regarding correlations between the individual proportions of humming melodic contours and the individual proportions of infants' overlapping vocalizations in each melodic contour, only one significant correlation ($r = .587$, $p = .005$) was found, which was for the U-shaped contour.

Discussion

This study allowed to know the characteristics of the melodic contours of maternal humming directed to preterm infants. This underlines the importance of the communicative function of those melodic contours for the infants' responsiveness namely its overlapping vocalizations. In our sample, when mothers hum to their preterm infants in kangaroo care a predominance of sinusoidal contours, followed by bell-shaped, rising, falling, U-shaped, and, finally, linear contours was found. Furthermore, the individual proportion of U-shaped contours is significantly lower than both bell-shaped and sinusoidal contours. Regarding the lengths of melodic contours, sinusoidal contours are the longest ones while the linear contours are the shortest. The bell-shaped contour is significantly longer than the U-shaped contour, and rising and falling contours do not vary significantly in length. However, we do not know to what extent the different proportions of the melodic contours of humming might be associated with the infant's behavioral signs, with their health status or with the cultural and individual differences of the dyads.

Sinusoidal contours in singing are more frequent in soothing than in speech contexts (Falk, 2011) and it has been shown that sinusoidal and bell-shaped contours are predominantly present in lullabies whose function is to calm the infant and to ensure a soothing environment (Cordes, 2005; Papousek, 1996). In the same way, when mothers of our sample hum to their preterm infants, they seem to hum in a lullaby style with a predominance of sinusoidal and bell-shaped contours. Some of these melodies were easily identifiable as lullabies of the traditional musical repertoire such as "Rock-a-bye Baby" and "Wiegenlied: Guten Abend, Guten Nacht" by Johannes Brahms. Moreover, those melodies that we were unable to associate with familiar repertoires were composed by repeated sinusoidal and bell-shaped contours associated with a lullaby style. Taking in account that mothers in our sample had no formal musical background, their option between melodies based and non-based on known musical repertoire could not be influenced by that factor.

Lullabies are often used in the context of neonatal music therapy in order to allow preterm infants to self-regulate (Haslbeck & Bassler, 2018; Haslbeck et al., 2020; Loewy, 2015). Also, the use of contingent singing or humming in a lullaby style plays an important role in promoting the self-regulation of very vulnerable hospitalized infants (Haslbeck et al., 2020; Loewy, 2015; Shoemark, 2018). Also, it seems that mothers in our sample used this humming lullaby style probably in order to maintain the infant's self-regulation; nonetheless, our data do not allow us to conclude about this matter. Furthermore, it would be interesting to observe if the infant's behavioral state can influence the maternal humming style as it has been suggested in the literature (Filippa et al., 2018). In addition, it is possible that the condition of stress and emotional vulnerability of preterm dyads while in NICU make it difficult for maternal contingent singing to be used in a spontaneous way. However, this study only explores the melodic contours of maternal humming in the absence of the orientation of a music therapist. This guidance would be important in order to promote the maternal reading of the infant's behavior and this way guiding maternal singing in order to adjust it to the infant's messages. Future studies are needed to analyze the melodic contours of the maternal contingent singing and humming.

According to Longhi (2009), maternal ID singing conveys the hierarchical structure of the song through multimodal sensory information. This multimodal experience in maternal singing or humming is helpful for infants' self-regulation. Several mothers in our sample seemed to synchronize their humming with their sway motions. This was not formally assessed but possibly it is relevant to understand the role played by these multimodal temporal cues that mothers provide for their infants. In our study, mothers positioned their bodies in a way that favored eye-to-eye contact with their infants; an analysis of the timing of the maternal gaze may provide further insight into the multimodal organization of ID communicative behavior. We do not know whether the swaying of the mother's upper torso matches the phrase timing and the melodic contouring of their humming, which would improve a synchronous proprioceptive experience for infants held in skin-to-skin and in visual contact. The specific organization of these multimodal cues remains to be investigated as well as their function in regulating infants' states and providing opportunities for social interaction.

Concerning infants' vocal responsiveness, a predominance of infants' overlapping vocalizations was found in sinusoidal contours followed by bell-shaped and rising contours, while in U-shaped contours, these vocalizations were scarce and totally absent in linear contours. This suggests that the sinusoidal, bell-shaped, and rising contours increase the infants' vocal responsiveness while U-shaped and linear contours do not. Probably, linear contours are prone to decrease the infants' arousal leading to a reduction of the infants' overlapping vocalizations. Furthermore, a higher frequency of infants' overlapping vocalizations was found in sinusoidal and in bell-shaped contours than in U-shaped contours, and these differences are significant. It is likely that the bell-shaped contour during humming, helping to close a curve that ends in a fall, leads the infant to anticipate this fall through a vocal response. It is possible that this experience of anticipation plays a role in decreasing arousal and helping the infant to self-regulate. Likewise, the sinusoidal contour can encourage the infant's vocal responsiveness while ensuring the maintenance of a moderate state of attention.

The infant's vocal responsiveness during these melodic contours could also be associated with a high frequency and length of sinusoidal and bell-shaped contours in humming. However, only a significant correlation was found between the frequency of the U-shaped contours and the infant's overlapping vocalizations during the U-shaped contours. This suggests that the infant's overlapping vocalizations may be contingently associated with the U-shaped contours.

We can also question if the absence or decrease in the infant's overlapping vocalizations mean active listening rather than a lack of engagement. In addition, the infants' health status and their individual differences may have contributed to their higher or lower vocal responsiveness. Considering the singing or humming as an interactive multimodal experience, in addition to melodic contours, other factors (such as maternal touch and swing) may have influenced the increase or the decrease of the infants' vocal responsiveness.

Limitations

The limitation due to the number of participants must be considered. As this is not a naturalistic observational study, we can question whether the lack of spontaneity, intimacy, and privacy of the participating dyads may have influenced the expressiveness of maternal humming directed to the preterm infant. It is possible that this leads mothers to hum in a socially desired style which is not attuned to the infant's needs. Future studies should deepen the knowledge about the possible influence of melodic contours of maternal humming for the infants' self-regulation. The evaluation of the preterm infant's physiological parameters (heart rate and oxygen saturation) captured during the production of the melodic contours of the humming will allow us to deepen this issue in a near future.

As we had no access to the health condition of each preterm infant at the time of observation, this could have compromised the infant's engagement as well as have influenced the humming style of the mothers. However, we excluded dyads with preterm infants who presented instability of vital parameters, CIPAP support, intraventricular hemorrhages, congenital or neurological anomalies of the auditory cortex, use of a nasogastric tube, and supported breathing. All these parameters were granted by the nursing staff ensuring the homogeneity of the infants' health status.

Although the interactive experience mediated by maternal humming is a multimodal experience this study did not investigate whether maternal touch and swaying during humming influenced the infant's vocal production. Multimodal observations of maternal humming directed to preterm infants must be included in future studies.

Conclusion

This study contributes to deepen the knowledge about the melodic contours of maternal humming directed to preterm infants during kangaroo care in NICU without a music therapist intervention. It also contributes to understand how preterm mothers, intuitively, orient their melodic contours while humming in order to promote the infants' engagement namely with their overlapping vocalizations. We believe that this study encourages the development of future studies about the communicative function of the melodic contours of contingent humming sustained by a certificated music therapist in order to improve the self-regulation of preterm infants in the context of NICU's. Favoring the maternal humming can be seen as a strategy to facilitate the task of the preterm mother; possibly the attunement between the mother and the infant can be easier to achieve when the mother sings without words than when singing with words. However, as this hypothesis was not tested yet we expect to study it soon.

Acknowledgements

The paper was proofread by Melaina Barnes, an editor financed by CESEM. The authors would like to thank the Ethical Committee of the Central Lisbon University Hospital Center as well as the nursing team and the medical team of the NICU of Maternidade Dr Alfredo da Costa who actively engaged in the process.

Authors' contribution

The first two and the fourth authors contributed to the design of the research. The first author collected and coded the data. The first two authors performed the statistical analysis and wrote the text of the paper. The third author contributed to the reliability of the coding of melodic contours. The fourth and the fifth authors reviewed the text and contributed to the final version of the paper.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author received no financial support for the research, authorship, and/or publication of this article.

ORCID iDs

Maria Eduarda Salgado Carvalho https://orcid.org/0000-0002-6315-5603

Helena Ferreira Rodrigues https://orcid.org/0000-0003-4519-6716

References

Arnon, S., Diamant, C., Bauer, S., Regev, R., Sirota, G., & Litmanovitz, I. (2014). Maternal singing during kangaroo care led to autonomic stability in preterm infants and reduced maternal anxiety. *Acta Pædiatrica, 103*, 1039–1044. https://doi.org/10.1111/apa.12744

Boersma, P., & Weenink, D. (2001). Praat: A system for doing phonetics by computer. *Glot International, 5*(9/10), 341–347. https://www.researchgate.net/publication/208032992

Brazelton, T. B., & Nugent, J. K. (2011). *The Neonatal Behavioral Assessment Scale* (4th ed.). Mac Keith Press.

Buil, A., Carchon, I., Apter, G., Laborne, F. X., Gratier, M., & Devouche, E. (2016). Kangaroo supported diagonal flexion positioning: New insights into skin-to-skin contact for communication between mothers and very preterm infants. *Archives de Pédiatrie, 23*, 913–920. https://doi.org/10.1016/j.arcped.2016.04.023

Carvalho, M. E., Justo, J. M., Gratier, M., & Rodrigues, H. (2020). Infants' overlapping vocalizations during maternal humming: Contributions to the synchronization of preterm dyads. *Psychology of Music, 49*(6), 1654–1670. https://doi.org/10.1177/0305735620968920

Carvalho, M. E., Justo, J. M., Gratier, M., Tomé, T., Pereira, E., & Rodrigues, H. (2019). Vocal responsiveness of preterm infants to maternal infant-directed speaking and singing during skin-to-skin contact (Kangaroo Care) in the NICU. *Infant Behavior and Development, 57, Article 101332*. https://doi.org/10.1016/j.infbeh.2019.101332

Cordes, I. (2005). *Der Zusammenhang kultureller und biologischer Ausdrucksmuster in der Musik*. Lit Verlag. https://www.amazon.de/Zusammenhang-kultureller-biologischer-Ausdrucksmuster-Musikpsychologie/dp/3825875822

Falk, S. (2011). Melodic versus intonational coding of communicative functions: A comparison of tonal contours in infant-directed song and speech. *Psychomusicology: Music, Mind and Brain, 21(1–2), 54–68*. https://doi.org/10.1037/h0094004

Fernald, A. (1989). Intonation and communicative intent in mothers' speech to infants: Is the melody the message? *Child Development, 60*(6), 1497–1510. https://doi.org/10.2307/1130938

Filippa, M., Della Casa, E., D'amico, R., Picciolini, O., Lunardi, C., Sansavini, A., & Ferrari, F. (2021). Effects of early vocal contact in the neonatal intensive care unit: Study protocol for a multi-centre, randomised clinical trial. *International Journal of Environmental Research and Public Health, 18*, Article 3915. https://doi.org/10.3390/ijerph18083915

Filippa, M., Gratier, M., Devouche, E., & Grandjean, D. (2018). Changes in infant-directed speech and song are related to pre-term infant facial expression in the neonatal intensive care unit. *Interaction Studies, 19*(3), 427–444. https://doi.org/10.1075/is.16019.fil

Fluharty, M., Nemeth, L. S., Logan, A., & Nichols, M. (2021). What do neonatal intensive care unit policies tell us about kangaroo care implementation? A realist review. *Advances in Neonatal Care, 21*(4), E76–E85. https://doi.org/10.1097/ANC.0000000000000808

Granier-Deferre, C., Bassereau, S., Ribeiro, A., Jacquet, A.-Y., & Decasper, A.J. (2011). A melodic contour repeatedly experienced by human near-term fetuses elicits a profound cardiac reaction one month after birth. *PLoS ONE, 6*(2), Article e17304.

Granier-Deferre, C., Ribeiro, A., Jacquet, A.-Y., & Bassereau, S. (2011). Near-term fetuses process temporal features of speech. *Developmental Science, 14*(2), 336–352. https://doi.org/10.1111/j.1467-7687.2010.00978.x

Gratier, M., Devouche, E., Guellai, B., Infanti, R., Yilmaz, E., & Parlato-Oliveira, E. (2015). Early development of turn-taking in vocal interaction between mothers and infants. *Frontiers in Psychology, 6*, Article 1167. https://doi.org/10.3389/fpsyg.2015.01167

Haslbeck, F. B., & Bassler, D. (2018). Music from the very beginning—A neuroscience-based framework for music as therapy for preterm infants and their parents. *Frontiers in Behavioral Neuroscience, 12*, Article 112. https://doi.org/10.3389/fnbeh.2018.00112

Haslbeck, F. B., Jakab, A., Held, U., Bassler, D., Bucher, H.-U., & Hagmann, C. (2020). Creative music therapy to promote brain function and brain structure in preterm infants: A randomized controlled pilot study. *NeuroImage: Clinical, 25*, Article 102171. https://doi.org/10.1016/j.nicl.2020.102171

Katz, G. S., Cohn, J. F., & Moore, C. A. (1996). A combination of vocal f0 dynamic and summary features discriminates between three pragmatic categories of infant-directed speech. *Child Development*, *67*(1), 205–217. https://doi.org/10.1111/j.1467-8624.1996.tb01729.x

Kostilainen, K., Partanen, E., Mikkola, K., Wikström, V., Pakarinen, S., Fellman, V., & Huotilainen, M. (2021). Repeated parental singing during kangaroo care improved neural processing of speech sound changes in preterm infants at term age. *Frontiers in Neuroscience*, *15*, Article 686027. https://doi.org/10.3389/fnins.2021.686027

Loewy, J. (2015). NICU music therapy: Song of kin as critical lullaby in research and practice. *Annals of the New York Academy of Sciences*, *1337*, 178–185. https://doi.org/10.1111/nyas.12648

Longhi, E. (2009). 'Songese': Maternal structuring of musical interaction with infants. *Psychology of Music*, *37*(2), 195–213. https://doi.org/10.1177/0305735608097042

Malloch, S., & Trevarthen, C. (2009). Musicality: Communicating the vitality and interests of life. In S. Malloch & C. Trevarthen (Eds.), *Communicative musicality: Exploring the basis of human companionship* (pp. 1–11). Oxford University Press. https://www.researchgate.net/publication/264857700_Musicality_Communicating_the_vitality_and_interests_of_life

Papousek, M. (1996). Intuitive parenting: A hidden source of musical stimulation in infancy. In I. Deliege & J. Sloboda (Eds.), *Musical beginnings. Origins and development of musical competence* (pp. 88–112). Oxford University Press.

Papousek, M., Papousek, H., & Symmes, D. (1991). The meanings of melodies in motherese in tone and stress languages. *Infant Behavior and Development*, *14*(4), 415–440. https://doi.org/10.1016/0163-6383(91)90031-M

Partanen, E., Kujala, T., Tervaniemi, M., & Huotilainen, M. (2013). Prenatal music exposure induces long-term neural effects. *PLoS ONE*, *8*(10), Article e78946.

Pelaez, M., Ortega, J. V., & Gewirtz, J. L. (2011). Reinforcement of vocalizations through contingent vocal imitation. *Journal of Applied Behavior Analysis*, *44*, 33–40. https://doi.org/10.1901/jaba.2011.44-33

Rosenthal, M. (1982). Vocal dialogues in the neonatal period. *Developmental Psychology*, *18*, 17–21. https://doi.org/10.1037/0012-1649.18.1.17

Shenfield, T., Trehub, S. E., & Nakata, T. (2003). Maternal singing modulates infant arousal. *Psychology of Music*, *31*(4), 365–375. https://doi.org/10.1177/03057356030314002

Shoemark, H. (2011). Contingent singing: The musicality of companionship with the hospitalized newborn infant. In F. Baker & S. Uhlig (Eds.), *Therapeutic voice work in music therapy* (pp. 229–249). Jessica Kingsley.

Shoemark, H. (2018). Time Together: A feasible program to promote parent-infant interaction in the NICU. *Music Therapy Perspectives*, *36*(1), 6–16. https://doi.org/10.1093/mtp/mix004

Shoemark, H. (2019). Returning musicality to parents: Constructing a strategy using parental voice. *International Journal for Birth and Parent Education*, *6*(2), 29–32.

Shoemark, H., Dahlstrøm, M., Bedford, O., & Stewart, L. (2021). The effect of a voice-centered psycho-educational program on maternal self-efficacy: A feasibility study. *International Journal of Environmental Research and Public Health*, *18*, Article 2537. https://doi.org/10.3390/ijerph18052537

Shoemark, H., & Grocke, D. (2010). The markers of interplay between the music therapist and the high risk newborn infant. *Journal of Music Therapy*, *47*, 306–334. https://doi.org/10.1093/jmt/47.4.306

Trainor, L. J. (1996). Infant preferences for infant-directed versus non infant-directed playsongs and lullabies. *Infants Behaviour and Development*, *19*(1), 83–92. https://doi.org/10.1016/S0163-6383(96)90046-6

Trainor, L. J., Clark, E. D., Huntley, A., & Adams, B. A. (1997). The acoustic basis of preferences for infant-directed singing. *Infant Behavior and Development*, *20*(3), 383–396. https://doi.org/10.1016/S0163-6383(97)90009-6

Trainor, L. J., & Zacharias, C. A. (1998). Infants prefer higher-pitched singing. *Infant Behavior and Development*, *21*(4), 799–806. https://doi.org/10.1016/S0163-6383(98)90047-9

Trehub, S. E., Bull, D., & Thorpe, L. A. (1984). Infants' perception of melodies: The role of melodic contour. *Child Development*, *55*(3), 821–830. https://doi.org/10.1111/j.1467-8624.1984.tb03819.x

Trehub, S. E., Hill, D. S., & Kamenetsky, S. B. (1997). Parents' sung performances for infants. *Canadian Journal of Experimental Psychology*, *51*(4), 385–396. https://doi.org/10.1037/1196-1961.51.4.385

Trehub, S. E., & Trainor, L. (1998). Singing to infants: Lullabies and play songs. *Advances in Infancy Research*, *12*, 43–78. https://www.researchgate.net/publication/285504507_Singing_to_infants_Lullabies_and_play_songs

Trehub, S. E., Unyk, A. M., & Trainor, L. J. (1993a). Maternal singing in cross-cultural perspective. *Infant Behavior and Development*, *16*(3), 285–295. https://doi.org/10.1016/0163-6383(93)80036-8

Trehub, S. E., Unyk, A. M., & Trainor, L. J. (1993b). Adults identify infant-directed music across cultures. *Infant Behavior and Development*, *16*(2), 193–211. https://doi.org/10.1016/0163-6383(93)80017-3

Trevarthen, C. (1993). The self-born in intersubjectivity: The psychology of an infant communicating. In U. Neisser (Ed.), *The perceived self: Ecological and interpersonal sources of self-knowledge* (pp. 121–173). Cambridge University Press. https://doi.org/10.1017/CBO9780511664007.009

Unyk, A. M., Trehub, S. E., Trainor, L. J., & Schellenberg, G. E. (1992). Lullabies and simplicity: A cross-cultural perspective. *Psychology of Music*, *20*(1), 15–28. https://doi.org/10.1177/03057356

Vannasing, P., Flore, O., González-Rankenberger, B., Tremblay, J., Paquette, N., Safi, D., Wallois, F., Lepore, F., Béland, R., Lassonde, M., & Gallagher, A. (2016). Distinct hemispheric specializations for native and non-native languages in one-day-old newborns identified by fNIRS. *Neuropsychologia*, *84*, 63–69. https://doi.org/10.1016/j.neuropsychologia.2016.01.038