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Creating a prenatal song for an unborn infant during a music therapy program: A longitudinal and microanalytic case study from before birth to three months of age

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ABSTRACT

Introduction: In music therapy the prenatal songs for unborn infants have been shown to improve prenatal bonding, but we know little about their contribution to the first vocal interactions between mothers and infants up to three months of age. We aimed to explore: (a) the development of maternal singing from gestation until three months of age; (b) fetal and infant responsiveness to a prenatal song and (c) the effect of infant's vocal responsiveness at three months of age for the tonal modulation of maternal singing.

Method: A case study of a mother—infant dyad was carried out in a music therapy program where a prenatal song for the unborn infant was created. A video recording of the dyad's interaction was made based on a protocol where the mother hummed an improvised tune and sang the prenatal song to the unborn infant (during a 4D interactive ultrasound) and to the infant at nine days and three months of age. A microanalysis of the fetal movements and the dyad's vocalizations was carried out.

Results: We found (a) an episode of fetal motor self-exploration after exposure to the prenatal song, (b) significantly longer infant vocalizations during the prenatal song than during humming ($p = 0.01$) and silence ($p = 0.03$) at three months of age, and (c) an increase of pitch in maternal singing following infant vocalizations.

Discussion: This study underlined the role of the prenatal singing to promote the interaction between parents and unborn infant and to improve the infant's vocal responsiveness at three months of age.

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KEYWORDS Prenatal music therapy; prenatal song; maternal singing; 4D interactive ultrasound; fetal movements; infant's vocalizations; microanalysis

Background

The maternal voice, as a primordial human experience in the transition from prenatal to postnatal life (Carvalho et al., 2019) seems to play a crucial role in the development of communicative musicality (Malloch & Trevarthen, 2009) and in the proto-development of primary intersubjectivity (Trevarthen, 1993). It is common for

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mothers to sing and hum to infants from birth. However, we still know little about the benefits of using prenatal singing, and particularly the use of prenatal songs written for an unborn infant in music therapy programs (Carvalho, 2015; Federico, 2001).

Previous studies on the impact of music on the unborn infant observed an auditory sensitivity to sound from a very early age of gestation. At this stage of development the fetus responds to intravaginal emissions of music with facial movements and repetitive mouthing and tongue expulsion (López-Teijó et al., 2015). Fetuses at term are able to discriminate between linguistic and musical stimuli such as ascending and descending melodies (Granier-Deferre et al., 2011b). The prenatal exposure to a descending melody can induce a profound cardiac reaction from the newborn at six weeks after birth when exposed to these descending melody (Granier-Deferre et al., 2011a). In a study of 12 fetuses, exposure to a melody (Twinkle twinkle little star) five times per week in the last trimester of gestation induced a neurological response in the newborns that lasted up to four months after birth (Partanen et al., 2013).

At 33 weeks of gestation, the left temporal cortex was significantly more activated during exposure to human voices (maternal and unfamiliar female voices) than during exposure to pure tones; at 34 weeks of gestation there was a significantly higher activation of the lower bank of the left temporal lobe in response to the maternal voice than to an unfamiliar female voice (Jardri et al., 2012). Fetal cardiac responses to the maternal voice start at 32 weeks of gestation (Kisilevsky & Hains, 2011; Kisilevsky et al., 2003) but fetal motor behavior has only been found in the 36th week of gestation when the mother's voice is transmitted live (Hepper et al., 1993; Krueger et al., 2015; Moon & Fifer, 2000). A decrease of fetal yawning (which is probably an indicator of fetal attention) has been found in response to maternal speech when compared with maternal touch (Marx & Nagy, 2015). During maternal singing (LA syllable versus LU syllable), an increase in fetal mouth opening (a possible indicator of fetal responsiveness) has been found in response to maternal singing of the LA syllable (Ferrari et al., 2016). An increase in self-exploration behavior (fetal hand toward mouth and lower face) has been emphasized as a marker of the fetal neurological maturation of full-term infants (Reissland et al., 2013). This self-exploration behavior has been found in preterm infants when mothers spoke or sang to them in the NICU (Filippa et al., 2020).

The role of maternal singing to improve the mother—infant interaction has been underlined in several studies (Haslbeck & Hugoson, 2017; Palazzi et al., 2020; Persico et al., 2017). Infant directed (ID) singing may have a communicative function for the infant's self-regulation, keeping the infant calm or in a moderate state of arousal (Trainor, 1996; Trainor et al., 1997). When compared to adult directed singing ID singing is characterized by a higher pitch, a slower tempo and a more intimate and expressive tone of voice (Trainor et al., 1997; Trainor & Zacharias, 1998; Trehub et al., 1993). These features might be due to the higher emotional involvement of the singer (Trehub & Trainor, 1998) and are more pronounced when the infant is present (Trainor, 1996; Trainor et al., 1997; Trehub et al., 1997). In the same way, maternal voice (speech or song) addressed to a preterm infant inside an incubator has shown an increase in pitch (F0) and maximum sound pressure level, with greater variability of these parameters after positive expressions by the infant such as opening their eyes, looking at their mother or smiling (Filippa et al., 2013, 2018). This suggests that infant behavior contributes to the mother—infant vocal interaction. At the end of gestation

the fetal movements seem to play a crucial role in the development of the first proto-dialogues as a precursor of early human intersubjectivity after birth (Delafield-Butt & Trevarthen, 2016).

The literature underlines the positive effects of singing in reducing stress and anxiety levels as indicated by the decrease in cortisol levels in adults in response to singing (Grape et al., 2002; Kreutz, 2014) and the release of oxytocin in response to group vocal improvisation (Keeler et al., 2015; Weinstein et al., 2016). Beneficial respiratory patterns and related cardiovascular benefits are found in response to vocal toning (improvised vocalization of free vowel sounds) in pregnant women (Pierce, 1998) and improvised singing and toning in adults (Bernardi et al., 2017; Snow et al., 2018).

The use of prenatal singing is connected with maternal perception of greater emotional closeness to the infant as well as with an increase in positive affect and a decrease in maternal anxiety (Carolan et al., 2012; Fancourt & Perkins, 2018; Persico et al., 2017; Teckenberg-Jansson et al., 2019; Wulff et al., 2021). A prenatal study of music therapy with 172 pregnant women (Wulff et al., 2021) compared musical listening intervention (CD with music for relaxation effect) to a prenatal singing intervention (using children's songs and lullabies accompanied by guitar by the music therapist) and a control group (without intervention). Both interventions (musical listening and singing) were carried out between 30- and 36-weeks' gestation. A significant decrease in cortisol (as a marker of stress) as well as a significant increase in oxytocin (as a marker of bonding) were found for the participants of both intervention groups, with a significant higher decrease in cortisol for the mothers in the prenatal singing group than mothers in the musical listening group (Wulff et al., 2021).

Mothers singing lullabies during gestation and after birth improved maternal—infant postnatal bonding (using the Mother-to-Infant Bonding Scale) three months after birth (Persico et al., 2017). In the same way, the use of lullabies (or humming in a lullaby style) in neonatal music therapy has had positive effects on the development of attachment in preterm dyads (Loewy, 2015) as well on the homeostatic mechanisms of the infant during painful procedures (Ullsten et al., 2017). Songwriting by parents to preterm infants in the context of a music therapy program in a neonatal intensive care unit (NICU) has also had positive effects on bonding, mental wellbeing, and anxiety levels as well as on lessening the depressive symptoms of parents (Ettenberger, 2018).

Songs by parents for their infants named song of kin (SOK) have been used in neonatal care in family-centered music therapy (Loewy et al., 2013; Loewy, 2015; Loewy & Jaschke, 2020), leading to an improvement in sucking behavior and an increase in the calorie intake of preterm infants (Loewy, 2015). In the clinical protocol of the “Rhythm, Breath and Lullaby training (Loewy, 2015, 2016), Loewy defined SOK as follows:

The “song of kin” (Loewy, 2015; Loewy et al., 2013) is inclusive of a model that assists parents in creating a natural, easily accessed sung melody, and most particularly one that has meaning for the parent. (. . .). It does not have to be a melody that the neonate heard in utero. It does not have to be related to spiritual or historical aspects one the infants' family. The song should aim to be a favored song-culturally relevant to parental preference, and the melody can be entrained and best applied with a simplified single-line matching of sung vocal phrasing. Accompaniment, if and when applied, can be minimal. (Loewy & Jaschke, 2020, p. 8)

Hospitalized pregnant women have experienced a decrease in prenatal stress and anxiety following live music therapy using humming in the style of a lullaby and playing the lyre (Teckenberg-Jansson et al., 2019). A greater synchronicity was found between mothers diagnosed with postpartum depression and their infants following a group experience with singing, vocal improvisation and movement than in a control group without these interventions (Van Puyvelde et al., 2014).

Early vocal contact between preterm dyads in the NICU without the involvement of a music therapist has been shown to promote intuitive parenting and parental communicative musicality (Filippa et al., 2021). Music therapy that uses contingent singing – that is, singing adjusted to the behavioral signs of hospitalized infants – has shown additional benefits to the infant’s self-regulation and to attunement of the preterm dyad. Attunement can be defined as

... a kinesthetic and emotional sensing of others knowing their rhythm, affect and experience by metaphorically being in their skin, and going beyond empathy to create a two-person experience of unbroken feeling connectedness by providing a reciprocal affect and/or resonating response. (Erskine, 1998, p. 3)

These emotional, sensorial, and empathic experiences can play a crucial role in preterm dyads in NICU improving their synchrony (Palazzi et al., 2020) and returning the musicality communicative to parents (Shoemark, 2019). It is possible that contingent singing may be a form to favor the development of the synchrony and the attunement in preterm dyads (Dahlstrøm et al., 2020; Haslbeck & Bassler, 2020; Shoemark, 2017, 2018, 2019). The benefits of contingent singing have been highlighted in the context of neonatal care and family-centered music therapy (Ettenberger, 2018; Loewy, 2015), in the clinical practice protocol of Creative Music Therapy in NICU (Haslbeck & Bassler, 2020), in the Time Together Program (Dahlstrøm et al., 2020; Shoemark, 2018, 2019), in the MUSIP protocol (Palazzi et al., 2021) and in the LongSTEP protocol (Ghetti et al., 2019).

Based on communicative musicality theory, microanalytic studies using video footage have been developed using the Neonatal Creative Music Therapy Method to understand the interactive synchrony of preterm dyads during the contingent musical interaction mediated by singing or humming (Haslbeck, 2014; Haslbeck & Hugoson, 2017; Shoemark, 2017). In addition, there is an ongoing multicentric study of longitudinal mixed methods using maternal singing in the NICU and after discharge (LongSTEP), with the goal to observe the impact of NICU music therapy, before and after hospital discharge, on child development, parental mental health and infant—parent interaction during the infant’s first two years (Ghetti et al., 2019). Nevertheless, maternal singing is mostly studied in the context of neonatal and postnatal music therapy rather than in prenatal music therapy. Also, most studies about ID singing have been carried out with infants over three months of age and there are very few transnatal studies of the effects of prenatal singing on the development of mother—infant interactions until three months of age (Persico et al., 2017).

Although the literature emphasizes the importance of maternal singing for the development of prenatal bonding, little is known about how maternal singing develops from before to after birth, and whether maternal singing can contribute to fetal neurological development and the vocal responsiveness of newborns and infants at three months of age. The aim of this study was to explore the development of maternal singing and its role in the mother—infant interaction from before birth to three

months of age. We intended to understand the fetal motor behavior (during an interactive 4D ultrasound at 33 weeks of gestation) and the infant responsiveness at nine days and at three months of age when the mother sang a prenatal song created during a prenatal music therapy process. The study also aimed at finding out more about the effect of infant's vocal responsiveness at three months of age for the tonal modulation (Flowers & Dunne-Sousa, 1990) of maternal singing.

Method

A method of songwriting by parents to their unborn infant (Carvalho, 2015), which has been termed a “welcome song”, has been integrated into the Mamisound's program, a prenatal music therapy method developed by Federico (2001) to promote prenatal bonding. The starting point for this study was a prenatal music therapy intervention with a group of five pregnant women (the fathers did not attend the sessions due to work commitments). We asked the mothers to create a prenatal song for their unborn infants encouraging father participation at home. Following the music therapy intervention, a longitudinal case study of one of the participating mothers was carried out.

Quantitative and qualitative methods were used (Baker, 2007; Creswell & Clark, 2017; Ridder, 2007) to carry out the microanalyses and an acoustic analysis of the mother—infant vocal interactions observed at three points: 33 weeks of gestation, during a 4D interactive ultrasound (Pulliainen et al., 2019), nine days after birth, and three months after birth.

The first observation was made at 33 weeks of gestation during a 4D interactive ultrasound at the Ultrasound Center (EcoX). The ultrasound image showed the face of the fetus in a 1 F/quiet sleep state characterized by low fetal heart rate variability (Nijhuis et al., 1982). The mother was invited to look at her fetus in the ultrasound monitor for one minute. Taking into account, that this observation could arouse a feeling of lack of privacy and intimacy in the mother, that could compromise her vocal expressiveness, a first period of adaptation to this observation condition was proposed, in which the mother was asked to address the fetus freely using speech and a melody without the use of words. After this first adaptation period, a 30-second period of silence was proposed as a baseline period before the mother sang the prenatal song that she had created with the father for her unborn infant during the music therapy process.

A similar procedure was adopted when the infant was nine days of age and three months of age. During these observations the mother was asked to speak and to hum an improvised melody, then she was asked to remain silent for a short time (30–45 seconds), and at last she was asked to sing the prenatal song. Figure 1 shows the study protocol.

Participants

The mother participant was selected taking into account her particular situation of anxiety and discomfort in singing. She was 31 years of age, of Portuguese nationality, married and a nurse working in a hospital in child psychiatry. This was her first pregnancy. The maternal perception of fetal movements began between 17 and 19 weeks of gestation. At the 22nd week of gestation the mother stopped at work, on medical advice due to an increase in blood pressure and to prevent an increase in stress

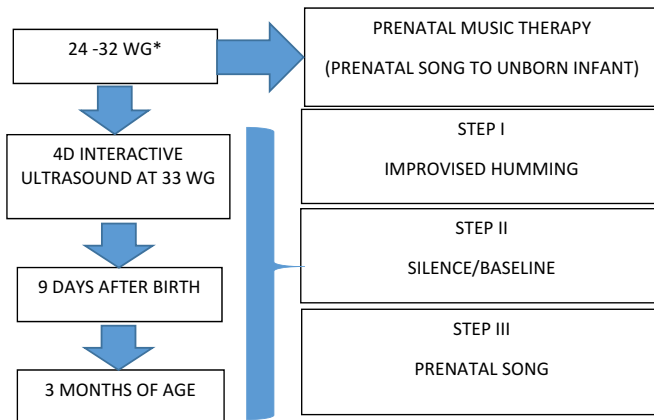


Figure 1. Study protocol. *WG Weeks of Gestation

and anxiety triggered in part by the pressure of her occupation. The main fears expressed by the mother were that she would lose the baby through miscarriage or that she would have a premature birth and that the father, who was frequently absent for work reasons, would not arrive in time to attend the birth as they both wanted. The mother was 24 weeks pregnant when she started the music therapy process. The main reasons for attending the music therapy group were to minimize periods of loneliness and anxiety and share experiences with other pregnant women. Another reason was to become more comfortable singing.

In terms of musical background, the mother had musical training and learned to play the violin as a child. She liked to listen to various styles of music such as classical music (baroque and renaissance), traditional Portuguese music, jazz, pop music, Brazilian and African music. She liked dancing, with African and Latin dances being one of the main forms of togetherness and communication for the couple. Unlike the child's father, the mother was not comfortable singing, which was one of the main reasons she wanted to attend the music therapy and prenatal singing program. She also had feelings of anxiety and loneliness because the child's father often had to be away for work reasons.

The infant's father was of Angolan nationality and was a military professional. He had a high level of musical education and was trained in classical guitar. He used music in his daily family and social life, playing guitar and ukulele to accompany himself singing.

Ethical considerations

This study followed the principles of the Declaration of Helsinki. After receiving information about the study, the participant gave written consent to participate in the study and to the inclusion of personal material, including images recorded on video and sound recordings for data analysis.

Music therapy intervention

The prenatal music therapy intervention took place at the Laboratory of Music and Communication in Infancy, which is part of CESEM (Centre for the Study of the Sociology and Aesthetics of Music) at Universidade NOVA de Lisboa. The program was for pregnant women from 20 weeks of gestation, and aimed to promote health and well-being. The music therapy intervention spanned the period from March to May 2019. There were 12 weekly sessions each lasting 90 minutes. [Table 1](#) displays the components of the prenatal music intervention according to the CONSORT and TREND guidelines for reporting interventions (Robb et al., 2011).

The mother in this case study participated in nine out of a total of 12 music therapy sessions. The first session was an individual session to establish a therapeutic relationship and to gather relevant information from the mother about her obstetric condition and the musical background of the parents. The second and third sessions were focused on creating group cohesion through body movement as a mediator of vocal expressiveness (using vocal toning, vocal holding and vocal improvisation based on simple melodic tunes in the style of a lullaby). From the fourth session onwards, each mother started to develop their own song that culminated in a prenatal song created for the unborn infant and sung in the music therapy sessions with the support of the group and the guitar or small harp of the music therapist. Both parents were present in the last session with the newborn infant.

The prenatal song for the unborn infant in the case study was created in the private environment of the pregnant couple and was titled Diana's Song (using the first name of the baby). The mother reported that the melody was created by the father based on a sequence of chords on the ukulele. The lyrics of the song were quickly improvised to go with the melody. The words were similar to the father's usual conversations with the unborn infant inside the womb. During music therapy sessions the mother started out by singing Diana's Song in a recitative style and the group accompanied her by humming. The mother progressed to singing the melody of the song but was always accompanied by the group and by the music therapist playing chords on the guitar. However, the mother reported that she sang Diana's Song and other songs at home when she was alone or accompanied by the baby's father.

Material and hardware

One video camera (Panasonic 4 K HC-VX870) was used with a tripod to record all music therapy sessions as well as the three observations of the dyad interaction (to see videos of dyad vocal interaction: [10.6084/m9.figshare.16750495](https://doi.org/10.6084/m9.figshare.16750495)).

For the first observation 4D interactive ultrasound (Pulliainen et al., 2019) was used to record the fetal motor behavior at the same time as the maternal singing directed to the fetus. Elan software (EUDICO Linguistic Annotator, version 4.9.4 <https://www.mpi.nl/corpus/html/elan/>) was used for microanalysis of the fetal movements and of the mother's and infant's vocalizations. A musical transcription of the prenatal song was made with MuseScore software (<https://musescore.org/en/download>)

Table 1. Description of the prenatal music therapy intervention according to reporting guidelines by Robb et al. (2011).*A: Intervention Theory*

Communicative Musicality Theory

B: Intervention Content

Prenatal music therapy program focused on a prenatal song created for an unborn infant

B.1: Person Selecting the Music

Music selected by participant and music therapist

B.2: Music

Group musical improvisation, lullabies of the world, improvised humming and song's writhing

B.3. Music Delivery Method (Live or Recorded)

Live prenatal singing in a group of five pregnant women.

B.4: Intervention Materials

Musical: piano, guitar, celtic harp, oceanic drum, bass xylophone, alto xylophone, monochord with 21 strings

Non-musical equipment: pilates balls, balloons, scarves, cushions; ultrasound equipment; video and microphone

B.5: Intervention Strategies

In order to promote the prenatal interaction between mother and unborn-infant, the following steps were proposed: (a) free musical group improvisation based on the sound environment of the womb with the following instruction: "let's take a trip to the womb"; (b) improvised humming by mothers to affectively connect with their unborn infants; (c) each mother was asked to graphically represent the pattern of foetal movements as if she were creating a rhythmic portrait of the unborn infant inside the womb; (d) each mother was invited to translate this rhythmic portrait into gestures, putting herself in the unborn infant's place inside the womb; and/or vocalize the infant's movements inside the womb from these graphic representations; (e) each mother sang the first name of their unborn infants with bodily movements; (f) each mother was asked to create a new song by changing the lyrics of an original song ("Hello baby") selected by the music therapist, to encourage dialogue with the baby in the womb, using the 'musical parody' technique (Baker et al., 2005); (g) finally each mother was encouraged to create with the participation of the father at home or other family members a special prenatal song for the unborn infant expressing feelings about the baby, so creating the baby's proto-identity and preparing for their birth through a welcome song (Federico, 2001).

C: Intervention Delivery Schedule

The prenatal music therapy group was conducted after an interview with each participant to sign the informed consent, and to collect relevant information about the obstetric and musical history. The group was made up of 12 weekly sessions, each lasting 90 minutes. After this intervention, one of the participants was accompanied by the music therapist for an ultrasound at 33 weeks of gestation and a new observation was made at nine days and three months of age during a musical sequence of maternal singing directed to infant (improvised humming and prenatal song)

D: Practitioner

A music therapist with training in prenatal and neonatal music therapy and certified by the Portuguese Music Therapy Association, a student of music therapy and a student of music education; technician specialized in 4D interactive ultrasound

E: Treatment Fidelity

The prenatal music therapy program is based on interventionist training and intervention monitoring developed by a music therapist with about 20 years of practising music therapy intervention in pregnancy

F: Setting

The music therapy intervention took place at LAMCI in a room with an intimate environment with good lighting and excellent acoustic quality protected from outside noise. The 4D interactive ultrasound took place at the Emotional Ultrasound Center (EcoX) in an intimate, safe and protective environment

G: Unit of Delivery

The prenatal music therapy intervention was undertaken by a group of five pregnant women between 20 weeks and 32 weeks of gestation, followed by the longitudinal observation of one of the dyads in a 4D ultrasound at 33 weeks of gestation, at nine days and three months of age during a musical sequence of maternal singing (improvised humming and prenatal song)

For acoustic analysis, Praat software (Dodane & Al-Tamimi, 2007; Owren, 2008) was used to obtain a spectrogram of the audio record, using a standardized method applied Linear Predictive Coding (LPC: <https://www.fon.hum.uva.nl/praat/manual/LPC.html>; <https://swphonetics.com/praat/objects-window/lpc-slices/>).

Microanalysis

Microanalysis of the temporal features of fetal movements and dyad vocalizations was performed using Elan software using the following parameters: (a) length of musical phrases and breathing pauses, measured in milliseconds (ms) in the prenatal song; (b) timing (ms) of fetal motor behavior; and (c) length (ms) of infant's vocalizations at three months of age. In order to ensure the reliability of the study, two researchers independently carried out the coding of the material.

For the microanalysis all videos and respective audio files for each of the three observations were transferred to Elan software in order to have real-time access to the image and spectrogram line of the vocalizations of the dyad. A vocalization was defined as an audible vocal segment from the mother's song or from the infant's vocal production that was visualized in the spectrogram of the audio recording. An episode of fetal motor behavior was defined as a trajectory of fetal movements (mouth opening, hand movements, hand movements toward the face or its features) that was visualized on the ultrasound monitor and recorded on video.

Using the Pratt tool we analyzed the vocal quality of the prenatal song based on the following features: (a) the fundamental frequency (F0) or the pitch that translates the vocal intonation; (b) the F1 formant, related to the opening of the mandible which translates into the hyper-articulation of vocal vowels (Dodane & Al-Tamimi, 2007; Song et al., 2010).

In accordance with the results of previous studies on preterm dyads (Filippa et al., 2013, 2018) we started with the hypothesis that the infant's vocal behavior at three months may contribute to a change in the vocal quality (F0 and F1) of the prenatal song sung by the mother. In order to analyse this hypothesis we estimated the average of pitch values (F0) of the same melodic phrase of the song before and after the infant's overlapping vocalizations. To analyze the F1 formant (hyper-articulation of the vowels related to the opening of the jaw) we selected the vowels "O" and "A" in two frequently used syllables of the song.

A musical transcription of the prenatal song was made with MuseScore software to analyse its musical characteristics as well as the infant vocalizations occurring at three months of age.

A complementary statistical analysis (t-Student) was carried out using SPSS Statistics 25 software to find out if there were differences in the temporal segmentation of the prenatal song in the three observations. The length of the infant's vocalizations at three months of age was compared in the prenatal song versus silence/baseline, and in the prenatal song versus improvised humming.

Results

Descriptive statistical analysis

A descriptive statistical analysis was carried out for each of the three observations to measure the length (in milliseconds) of the musical phrases and the length of the breathing pauses. The average length of musical phrases was highest at 33 weeks of gestation (M = 1623.68, SD = 1162.69). The average length of musical phrases at nine days of age (M = 1442.10, SD = 1120.81) was lower than at three months (M = 1569.41, SD = 1233.91). The average length of the breathing pauses was higher at three months of age (M = 911.76, SD = 528.92) than at nine days of age (M = 862.22, SD = 513.78)

and lowest at 33 weeks of gestation ($M = 817.68$, $SD = 347.65$). The average of beats per minute (bpm) of the prenatal song was also analyzed for the three observations; a similar value was detected at 33 weeks of gestation ($M = 125.1$) and at nine days of age ($M = 126.9$) but an increase was found at three months of age ($M = 143.6$). However, these differences were not statistically significant.

Acoustic analysis

The results showed an increase of 25.11% in the level of intensity of the sound pressure of the maternal voice immediately after the infant's overlapping vocalizations. Similar values were found for pitch (F0) at 33 weeks of gestation ($M = 255.17$, $SD = 25.09$) and at nine days of age ($M = 255.25$, $SD = 23.07$) but an increase of pitch (F0) was found at three months of age ($M = 260.84$, $SD = 28.46$). This value increases even more after the infant's overlapping vocalizations ($M = 273.92$, $SD = 24.98$).

The results showed a progressive increase in F1 values from 33 weeks of gestation ($M = 630.20$), to nine days of age ($M = 769.09$), to three months of age ($M = 810.26$). This value increased even more after the infant's overlapping vocalizations ($M = 879.93$).

Verbal and musical analysis

A qualitative analysis of the melodic, rhythmic, and verbal features of the prenatal song was performed for the three observation points. For each of the observations it was possible to identify three main cycles. Each cycle was comprised of three verses: (a) "Olá, estou aqui" ("Hello, I'm here"); (b) "Eu gosto de ti/Olha para mim" ("I love you/look at me"); and (c) "Olha pra quem te ama Diana" ("Look at who loves you, Diana").

Regarding the prenatal song there were small changes in some notes but the basic structure of the song did not change in the three observation periods. The rhythmic patterns were constant but appeared to be slower in the song directed to the fetus than in the song directed to the infant after birth. When the infant was nine days old, we observed that the mother's intonations had shorter time values and, therefore, the melody had a more staccato rhythm. At three months of age, the rhythm of the song was more regular.

Fetal and infant responsiveness

The coding of the fetal behavior at 33 weeks of gestation was performed using Elan software. After the beginning of the prenatal song, there was a change in fetal motor behavior, with self-exploration movements of the hand to face (finger in the nose and finger in contact with the lips). Similar self-exploration movements were found when the mother improvised a song with words about the infant's father.

At nine days of age, there were no infant vocalizations, but when the mother sang the prenatal song we observed the infant's right-hand opening at the same time as the beginning of the musical phrase and also an accentuated sucking rhythm, which was in time with the musical phrase and the prosodic accentuation of the syllables of the text; we also observed a period of transition from a calm alert state to a state of drowsiness (eyes half closed with eyelid movements). After the end of the singing, we observed that the infant's gaze was directed toward the mother's face.

At three months of age, an infant vocal responsiveness was found when mother sang the prenatal song. Figure 2 shows the musical transcription of the prenatal song sung by the mother to the infant at three months of age, as well as the infant’s vocalizations (n = 19) among which we found a predominance of infant overlapping vocalizations (n = 14) during the musical phrases.

The proportion of the time in milliseconds (ms) of the infant’s vocalizations at three months age was estimated relative to the total time (ms) of three conditions: (a) silence/baseline (43.409 ms), (b) improvised humming (59.990 ms) and (c) prenatal song (42.250 ms). Figure 3 illustrates the proportion of time for each of the three conditions. A descriptive statistical analysis of the length of the vocalizations showed the highest values for the prenatal song (M = 713.37, SD = 199.18), followed by silence/baseline (M = 599.23, SD = 209.62) and then improvised humming (M = 507.73, SD = 227.20). Significant statistical differences were found between the average length of infant vocalizations during (a) prenatal song versus silence/baseline (t = -2.435, df = 12, p = 0.03) and (b) prenatal song versus humming (t = - 2.782, df = 18, p = 0.01). Furthermore, at three months the infant’s overlapping vocalizations during the prenatal song occurred predominantly at the end of a phrase, on the strong beat of the measure, and on the accents of the text. In the first cycle we noted that of the seven overlapping vocalizations, four fell on the accentuation of the last syllable of the words “ti” (you), “Olha” (Look), and “Diana”, which correspond to the note D flat, the keynote of the song.

Discussion

This study underlined the role of prenatal music therapy to promote the use of maternal singing from before birth. Considering the initial discomfort of the mother related to use her singing voice, the music therapy intervention in the prenatal period seemed to help her to overcome her inhibition of singing. A substantial and progressive improvement in the expressiveness and spontaneity of the mother’s singing as well as in the prosodic quality of the mother’s voice while speaking to the infant at three months of age were found.



Figure 2. Prenatal song at 3 months of age. First and second cycle

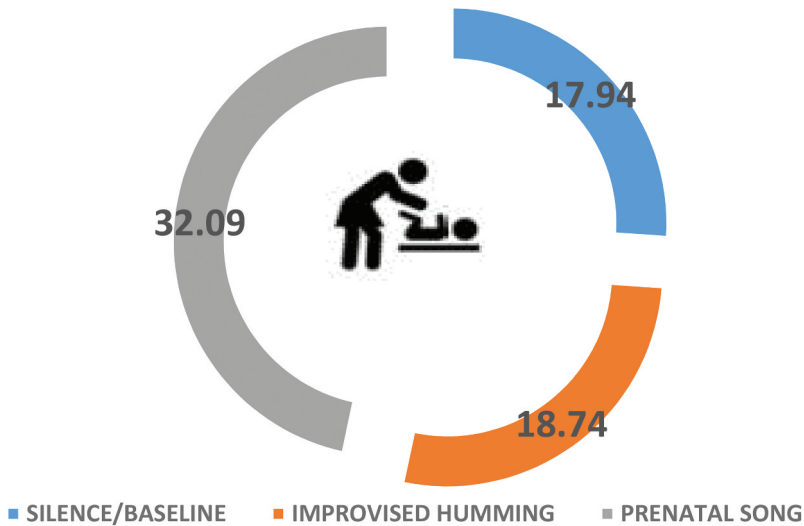


Figure 3. Proportion (%) of infant vocalizations during improvised humming, silence/baseline, and prenatal song

At the first observation of the fetus during the 4D interactive ultrasound, it was possible to see that at the beginning of the prenatal song, there was a change in fetal motor behavior through the fetus' self-exploration movements of the face (hand and finger to the nose). Similar movements of self-exploration of the face in preterm newborns were found when they were exposed to the maternal voice (Filippa et al., 2020). According to the literature, the increase of self-exploration movements directed to the lower region of the fetal face, as well as the occurrence of anticipatory mouth movements through mouth opening that precedes hand-to-mouth contact (Reissland et al., 2013) has been underlined as a crucial marker of fetal neurological maturation at the end of gestation. This suggests that maternal singing can play an important role in the early development of self-exploration, anticipation and motor planning; these can be considered as the first forms of thought and reflective behavior that underpin the ontogenesis of narrative and human intersubjectivity (Delafield-Butt & Trevarthen, 2016).

Regarding the first observation after birth of our study at nine days of age no infant vocal responsiveness was found. However, the orientation of the infant's gaze toward the mother's face when the maternal singing ended may suggest that the newborn was sensitive to the interruption of the maternal singing and was reacting to its absence. The observation of suction behavior synchronized with maternal singing seems to reinforce the importance of timing and timbre during contingent maternal singing, as emphasized by Loewy (2020).

Regarding the infant's vocalizations at three months, a higher proportion of infant vocalizations was found during the prenatal song than during the improvised humming. The mother was more emotionally involved when singing the prenatal song, and the prenatal song had a stronger temporal and melodic structure than the improvised humming, which may explain the infant's greater vocal responsiveness to the prenatal song than to the other conditions. As with the song of kin (Lowey & Jaschke, 2020), it is likely that the familiar characteristics of this prenatal song were associated with an

environment of intimacy between the pregnant couple, evoking the father's proximity in the interaction of the family triad. The infant probably sensed the emotional expression conveyed by the prenatal song and increased their vocal responsiveness.

Regarding the temporal and melodic patterning of this prenatal song, while the improvised humming seems to be less structured and less predictable, the prenatal song had a more predictable temporal structure similar to the structure of children's songs (Tsang & Conrad, 2009). It is possible that this structure favors the infant's vocal participation. The infant's ability to anticipate the song's repetition, timbre and patterning indicates the neuroplasticity of the infant's developing brain (Loewy & Jaschke, 2020). In the same way we found infant's overlapping vocalizations during the prenatal song mostly coincided with the end of the phrase (overlapping the final note or occurring immediately after the final note of the musical phrase), suggesting that the infant already has the capacity for anticipation. Previous studies support this finding (Carvalho et al., 2021; Gratier & Devouche, 2020).

Regarding the changes in acoustic features, our results suggest that the vocal participation of the three-month-old infant played a key role in the mother's vocal quality, demonstrated by increase in pitch (F0) and in vocal articulation, indicated by an increase in the formant (F1). According to the literature (Song et al., 2010), an increased formant shows the hyper-articulation of vowels, so we can suppose that in this case the increase of F1 in the maternal singing probably encouraged and reinforced the infant's vocal participation during the song. Similar observations were made in previous studies with preterm dyads (Filippa et al., 2018). The acoustic changes of pitch in maternal singing seem to be influenced by the infant's overlapping vocalizations, suggesting that the infant's vocal responsiveness at three months of age may play an important role in the vocal interaction between mother and infant. This underlines the mediating role of maternal signing for improving maternal–infant attunement (Erskine, 1998).

In our study, although the quantitative analysis did not show significant changes in the temporal structure of the singing in the three observation periods, we can observe an increase in the duration of breathing pauses in singing directed to the infant at three months of age, probably to give the infant an opportunity for more vocal participation. Regarding the musical features of the prenatal song, there was a slight variation in the melodic contour of the song in the three observation periods. This variation seems to relate to the developmental stage and the behavioral state of the infant. When directed to the fetus, the song was slower and had a more regular rhythmic pattern than at the other observation points. When directed to the infant at nine days old, a more staccato version of the song was sung. The infant was in a state of drowsiness at this observation, so the staccato style was probably a means of increasing the infant's attention.

Although pre- and postnatal exposure to the maternal voice has been emphasized in the literature, the father's voice can elicit event-related potentials (ERPs), which are patterns associated with recognition memory (Barthell et al., 2007). We recognize the importance of using the father's voice in music therapy interventions and involving the pregnant couple in the process (Barthell et al., 2007; Mondanaro et al., 2016). Despite the parents' inability to attend the sessions due to work commitments, their participation at home was encouraged throughout the music therapy process, and a final session was held with the presence of newborns and both parents. In our case study, the father could not be present during the music therapy sessions but we observed the father's active participation in creating a prenatal song for the unborn infant at home in the

couple's private environment. This prenatal song seemed to play a key role for the integration of the father in the music therapy process and contributed to connect the father to the unborn infant as well as to strengthen the connection between the pregnant couple. The narrative content of this song suggested the expression of a feeling of love toward the unborn infant and the anticipation of a future dialogic relationship with the infant after birth.

Limitations

The main limitations of this study were methodological, mainly in relation to the first observation of fetal motor behavior during the 4D interactive ultrasound. It was difficult to maintain the baseline fetal behavioral condition (F1 or F3) in the real-time observation of the fetus' motor responsiveness to live maternal voice stimulation. It was also difficult to maintain a steady image of the fetus's face in order to allow the observation of fetal motor behavior in real time. Also the order effect was not controlled in the sequence of maternal singing conditions, which limited the interpretation of the results related to the infant's responsiveness to the prenatal song compared to humming.

Implications for music therapy

This study contribute to encourage parents to musically stimulate their unborn infant, humming and singing to them. Creating a special song for the unborn infant can be a strategy to family connection, improving the first vocal interactions with the unborn infant and with the infant after birth. The use of a repeated prenatal song can to increase a predictability experience creating a bridge between the life before and after birth. The use of maternal singing during a 4D interactive ultrasound (Pulliainen et al., 2019) could be a strategy to connect the mother with the unborn infant as well as assessing neurological fetal motor responsiveness to maternal singing. Fetal movements have been seen to play a key role in the roots of maternal—fetal interaction (Di Pietro, 2010). So, when the mother sings to the unborn infant the fetal motor behavior visualized during the interactive 4D ultrasound can improve the maternal recognition of the unborn infant's responsiveness skills. This can play a crucial role in promoting maternal—fetal interaction and the development of prenatal bonding.

Future research

Previous studies have used listening to music as a maternal–fetal monitoring method and a non-stress test (He et al., 2021; Kumar et al., 2011), but further studies would be needed to assess live maternal singing as an alternative non-invasive maternal–fetal monitoring method. The impact of maternal singing on the heart rate variability of the fetus and on fetal movements would need to be evaluated to assess the impact of maternal singing on the critical information conveyed by the fetal nervous system.

The results suggest that the unborn infant responds actively (with self-exploratory motor behavior) during a singular prenatal song that the mother sings with emotional involvement. This self-exploratory behavior signals neuronal maturation of the fetus at term (Reissland et al., 2013). In this sense our study suggests that maternal singing can be a tool to improve fetal cognition by optimizing the mental and sensory development

of the unborn infant, which may enhance the development of the infant's brain from birth. More systematic strategies of the use of 4D interactive ultrasound to assess fetal motor responsiveness to live maternal singing deserve further exploration. Also, more microanalytical studies including acoustic and musical analyses, should be developed in the field of music therapy.

The participation of the father in creating the prenatal song for the unborn infant can play an important role in improving the engagement of both parents during the creative process of parenting from before birth. More studies of the father's singing voice are needed in order to understand the role of the father's voice in vocal interaction with the baby before and after birth. This could also deepen knowledge about how the fetus and the newborn baby respond to low-frequency signals, which has been highlighted in previous studies (Spence & Freeman, 1996).

Conclusion

Creating a prenatal song to the unborn infant as part of a music therapy program can improve the parental engagement during the gestation and the development of communicative musicality from before birth. A significant increase of infant's vocalizations at three months of age was found when mother sang the prenatal song; these infant vocalizations seemed to improve the maternal vocal engagement changing her tonal modulation. More studies are needed on the use of parental singing in the context of intervention programs in prenatal music therapy, and the active participation of the father is strongly recommended.

Disclosure statement

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