Effects of Maternal Singing Style on Mother–Infant Arousal and Behavior

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Abstract

Mothers around the world sing to infants, presumably to regulate their mood and arousal. Lullabies and playsongs differ stylistically and have distinctive goals. Mothers sing lullabies to soothe and calm infants and playsongs to engage and excite infants. In this study, mothers repeatedly sang *Twinkle, Twinkle, Little Star* to their infants (n = 30 dyads), alternating between soothing and playful renditions. Infant attention and mother–infant arousal (i.e., skin conductivity) were recorded continuously. During soothing renditions, mother and infant arousal decreased below initial levels as the singing progressed. During playful renditions, maternal and infant arousal remained stable. Moreover, infants exhibited greater attention to mother during playful renditions than during soothing renditions. Mothers’ playful renditions were faster, higher in pitch, louder, and characterized by greater pulse clarity than their soothing renditions. Mothers also produced more energetic rhythmic movements during their playful renditions. These findings highlight the contrastive nature and consequences of lullabies and playsongs.

INTRODUCTION

Infants are born into a musical world. Parents across cultures interact with infants by singing and moving rhythmically, often on a daily basis (for reviews, see Trehub & Cirelli, 2018; Trehub & Gudmundsdottir, 2015). Infants readily perceive the pitch and timing distinctions that are relevant for various musical cultures. For example, newborn neural responses indicate sensitivity to changes in tempo (Háden, Honing, Török, & Winkler, 2015) and pitch (Stefanics et al., 2009). A mere 2 months later, behavioral responses are evident to familiar melodies (Plantinga & Trainor, 2009) and rhythms (Demany, McKenzie, & Vurpillot, 1977). By 5 months of age, infants produce rhythmic movements in response to auditory rhythms (Zentner & Eerola, 2010). These perceptual and production skills set the stage for socially rich musical experiences, which have implications for social bonding and emotional regulation in infancy (Cirelli, 2018; Cirelli, Trehub, & Trainor, 2018; Corbeil, Trehub, & Peretz, 2016; Mehr, Song, & Spelke, 2016; Cirelli, Einarson, & Trainor, 2014; Ghazban, 2013). Parental songs arguably provide the most salient musical experiences in early life.

An infant-directed (ID) song, whether generated by caregivers or siblings, exhibits higher fundamental frequency (F0), slower tempo, and greater emotional expressiveness than a self-directed (SD) or adult-directed song (Nakata & Trehub, 2011; Trainor, 1996; Trehub, Unyk, & Henderson, 1994). Parents also smile more when singing to infants than when talking to them (Trehub, Plantinga, & Russo, 2016), which has acoustic as well as visual consequences (Tartter & Braun, 1994). Interestingly, parents are unable to produce these exquisitely tuned performances when their infants are absent or out of view (Trehub et al., 1997, 2016).

Infants respond enthusiastically to an ID song. Newborns and older infants exhibit greater attention to audio excerpts of ID than SD songs (Masataka, 1999; Trainor, 1996), raising the possibility of innate attentional biases for emotionally positive vocalizations. In line with this view, equally positive audio excerpts of ID song and speech capture infant attention with comparable efficacy (Corbeil, Trehub, & Peretz, 2013). In natural settings, however, Western caregivers generally sing to infants in face-to-face contexts, creating a multimodal experience (Trehub, 2018) in which visual features play a prominent role. Infants consistently accord greater attention to audio-visual recordings of ID songs than to ID speech, even when silent recordings are presented (Trehub et al., 2016; Costa-Giomi, 2014; Nakata & Trehub, 2004).

Across cultures and contexts, caregivers’ sung performances to infants vary in their soothing (lullaby-like) or playful (lively) style, each with distinctive acoustic correlates (Trehub & Trainor, 1998). Lullabies, which are readily identified across cultures (Mehr, Singh, York, Glowacki, & Krasnow, 2018; Trehub, Unyk, & Trainor, 1993), feature slower tempo, lower pitch level, and less dynamic variability than playsongs (Rock, Trainor, &
Mothers repeatedly sang the same song, between performance style and song structure or content. Arousal, as indexed by skin conductance (SC) levels, and soothing and playful renditions on alternating trials. We expected greater infant arousal reduction for soothing than for playful singing, consistent with the goals of these singing styles. We also expected greater infant attention to mother for playful than for soothing renditions. Although singing modulates singers’ arousal and mood (Sanal & Gorsev, 2013; Dunbar, Kaskatis, MacDonald, & Barra, 2012), there was no definitive basis for predicting the arousal consequences of soothing and playful renditions on mothers. Nevertheless, there is suggestive evidence that singing in the context of a mother–infant group reduces maternal cortisol levels (Fancourt & Perkins, 2018a, 2018b). In this study, we expected reductions in maternal arousal during soothing renditions either as a direct consequence of the soothing style of singing or as a secondary consequence of infant calming.

METHODS

Participants

We recruited primary caregivers with infants between 8 and 11 months of age, and mothers were the primary caregiver in all cases. Participants were 30 mother–infant dyads from middle-class families in a Canadian suburban community. One dyad was eliminated because of infant fussiness. In the final sample of 29 dyads (13 male and 16 female infants), infants were 8.25–11.07 months of age (M = 9.81 months, SD = 0.87 months), and mothers were 25–46 years of age (M = 34 years, SD = 4.74 years). Test sessions were scheduled at mothers’ convenience to accommodate infants’ napping and feeding routines. Mothers reported singing to their infants from 10 to 100 min/day (M = 35 min), and all claimed to sing for soothing and playful goals. Mothers sang during daily routines (sleep time, diaper change, bath time, playtime), and 22 of the 29 mothers sang Twinkle Twinkle Little Star to their infants. Other family members (21 father,
8 siblings, 14 grandparents) also sang to the infant on a regular basis. The University of Toronto research ethics board approved all data collection procedures, and informed consent was obtained from all mothers.

**Apparatus**

SC of mother and infant was obtained with the BIOPAC MP160 System in conjunction with AcqKnowledge 5.0 software, at a sampling rate of 100 Hz. Two pregelled, self-adhesive, Ag–AgCl electrodes were connected via leads to BIOPAC Bionomadix wireless EDA amplifiers. For mothers, electrodes were affixed to the distal phalanx of the left index and middle fingers, and the wireless amplifier was worn around the left wrist. For infants, electrodes were placed on the plantar surface of the right foot (see Figure 1A), and the amplifier was worn around the right ankle. The electrodes were taped in place with paper medical tape, and a large sock was placed on top of the infant’s foot to ensure continued contact and reduce amplifier movement. Data were recorded on a Windows 10 computer connected to the MP160 system. Video footage was recorded simultaneously by means of two camcorders (Sony Exmor R)—one directed at the infant and the other at the mother.

Instructions were presented to the mother on a computer screen behind the infant (i.e., out of the infant’s line of sight). An experimenter outside the sound-attenuating test room, who could see and hear mother-infant behavior via live audiovisual feed, transmitted on-screen prompts at appropriate times. Between trials, the screen indicated: “Please wait until you see ‘GO’ before beginning the next take. Next take is: ______ (Soothing/Playful) style.” When it was time for the mother to begin singing, the word “GO” was presented with the style (soothing/playful) indicated below. Mothers wore a Sony lapel microphone (ECM-55B), and their singing was recorded via Audacity.

**Procedure**

After obtaining consent, the experimenter led the dyad into the sound-attenuating test suite. The infant was placed in a highchair, and the mother sat facing the infant at an approximate distance of 1 m (see Figure 1B). The experimenter applied the electrodes to the infant’s foot and mother’s fingertips, as noted. An assistant entertained the infant by blowing bubbles while the sensors were applied. The mother was then asked to follow the on-screen prompts, singing one verse of *Twinkle Twinkle Little Star* and alternating between a soothing or playful manner of singing, as indicated. Start order (soothing/playful) was counterbalanced across participants. The mother was told that, between each take, there would be a 30-sec break during which she should keep the baby entertained and content without singing. Toys hidden below the highchair were available, if necessary, to help cope with infant fussiness. Once mothers used the toys, they remained available to infants for the remainder of the test session. The experimenter and assistant then left the room and began the audiovisual and SC recordings. The procedure continued until the infant became too distressed to continue or until 10 trials with each song style were completed. On average, the procedure lasted roughly 20 min. Subsequently, mothers completed a family background questionnaire.

**RESULTS**

**Trial Retention**

Trials in which naïve adults rated infants as distressed during the first or last 8 sec of a song or 8 sec preceding song onset (from silent videos) were excluded from all analyses detailed below. This procedure resulted in the removal of 23% of soothing trials and 18% of playful trials. Such trial exclusions did not differ significantly across song style, $p = .113$. Inclusion in the subsequent analyses required at least three trials in each song style.

**Skin Conductance**

Infant arousal, as reflected in SC levels, was expected to decrease (i.e., exhibit a negative slope) in response to soothing singing. SC data were exported into MATLAB.
Ledalab (V3) toolbox was used to downsample these data to 10 Hz, to visually identify and correct minor artifacts, and to extract tonic and phasic SC using the continuous decomposition analysis method (Benedek & Kaernbach, 2010). Trials with extreme artifacts were identified and excluded from further analyses. After noisy trial and fussy trial exclusions, 22 infants and 26 mothers met the minimum inclusion criteria of three trials per condition. On average, 6.5 ($SD = 1.8$) and 6.5 ($SD = 1.9$) soothing trials were retained, whereas 6.9 ($SD = 1.8$) and 6.7 ($SD = 1.9$) playful trials were retained for infants and mothers, respectively. These data were further processed in the MATLAB workspace. Because we were interested in slow changes in SC levels over the course of songs, tonic data were analyzed further.

Maternal song duration varied for each dyad because of tempo differences. To maximize data retention while optimizing cross-condition comparisons, trial length was determined within each dyad. For example, if the duration of Mother X’s shortest song trial was 14 sec, then 14 sec was used as trial maximum for all of Mother X’s and Baby X’s trials. Trials were baseline-corrected to the 5-sec presong onset. Grand-averaged SC levels are plotted for mothers and infants across the two song style conditions in Figure 2. Because the focus was on changes in SC levels in mother and infant as the songs unfolded, the slopes of the lines of best fit from trial onset until trial length maximum were computed for each trial. Mean slopes were then calculated for mother and infant SC level for each song style (Figure 3).

Mean slope of infant SC levels was steeper and more negative during soothing renditions than during playful renditions, $t(21) = −2.32, p = .03$ (paired-samples $t$ test). Mean SC level decreased over the course of soothing renditions, exhibiting a negative slope (one-sample test comparing mean slope to 0: $p = .006$), but comparable values for playful renditions remained stable (one-sample test comparing mean slope to 0: $p = .489$). This pattern of results was similar for the small set of infants who were unfamiliar with the song.

Maternal SC levels exhibited a similar pattern, with lower mean slope for soothing than for playful renditions, $t(25) = −2.85, p = .009$ (paired-samples $t$ test). Mean SC levels decreased over the course of soothing renditions (one-sample test comparing mean slope to 0: $p = .017$), but not for playful renditions (one-sample test comparing mean slope to 0: $p = .259$).

Maternal and infant SC levels were correlated across time on each trial for the 22 dyads with clean infant data. Mean correlations for soothing trials ($M$ Pearson $R = .21$) were significantly above 0, $t(21) = 3.18, p = .004$ (one-sample $t$ test), suggesting that mothers and infants responded synchronously. Mean correlations for playful trials ($M$ Pearson $R = .06$) did not differ from 0, $t(21) = 0.90, p = .377$ (one-sample $t$ test), but mean correlations across the two song styles (soothing, playful) did not differ significantly, $t(21) = 1.58, p = .128$ (paired-samples $t$ test), so these results should be interpreted with caution.

**Infant Behavior**

After fussy trial exclusions, 29 infants met the minimum inclusion criteria of three trials per condition for behavioral analyses. On average, 7.0 ($SD = 2.1$) soothing trials and 7.4 ($SD = 2.2$) playful trials were retained for each infant. To establish that mothers’ contrasting renditions had differential consequences on infant attention, a rater blind to the hypotheses and conditions coded silent 8-sec
videos of infants created from the first and last 8 sec of each trial (1 = completely inattentive to mother to 7 = completely attentive). Trials with poor visibility (e.g., view of infant temporarily obscured by mother’s arm) were removed. A second naïve rater rated 31% of the clips, with good interrater reliability, $R = .827$, $p < .001$. A repeated-measures ANOVA, with Song style (soothing, playful) and Time (first or last 8 sec of trial) as within-subject factors, revealed significantly greater attention during playful renditions ($M = 4.05$, $SD = 1.15$) than during soothing renditions ($M = 3.38$, $SD = 1.03$), $F(1, 28) = 23.72$, $p < .001$, $\eta^2_p = .459$, a significant effect of Time, $F(1, 28) = 29.46$, $p < .001$, $\eta^2_p = .513$, but no interaction between Song style and Time, $F(1, 28) = 0.32$, $p = .577$. Infant attention to mother decreased as the trial progressed (first 8 sec: $M = 4.01$, $SD = 1.08$; last 8 sec: $M = 3.43$, $SD = 1.05$).

**Maternal Song**

To assess the distinctiveness of maternal song renditions, audio recordings of each rendition were presented randomly to a rater who was unaware of the study hypotheses or singers’ intended song style. One mother’s recordings were unavailable because of equipment failure, resulting in 28 mothers for the following analyses. Renditions were rated on a scale of 1 (extremely soothing) to 7 (extremely playful). A second rater, also naïve to hypotheses and condition, rated 20% of the renditions with high interrater reliability, $R = .835$, $p < .001$. Mean ratings were calculated across soothing and playful trials for each mother. A paired-samples $t$ test revealed that soothing renditions were rated as very soothing ($M = 1.77$, $SD = 0.66$), with ratings significantly below the neutral midpoint of the rating scale, one-sample $t(27) = −17.80$, $p < .001$. These ratings differed significantly from playful renditions, $t(27) = 15.96$, $p < .001$. Playful renditions were rated as only moderately playful ($M = 4.93$, $SD = 1.21$), but they exceeded the neutral midpoint of the rating scale, one-sample $t(27) = 4.07$, $p < .001$.

To facilitate the quantification of acoustic features, infant sounds were removed from maternal renditions using Melodyne 3, and the filtered clips were processed with Mirtoolbox 1.7 running on MATLAB 2016a. Mean tempo, pulse clarity (i.e., strength of rhythmic periodicities), mean fundamental frequency (Hz), and root-mean-square (RMS) energy (i.e., audio power, a proxy for perceived loudness) were calculated across soothing and playful renditions for each mother. Paired-samples $t$ tests revealed that playful renditions had significantly higher pitch, faster tempo, greater pulse clarity, and greater RMS energy than soothing renditions ($all ps < .001$; see Table 1).

To quantify the differences in maternal rhythmic gestures, a rater blind to the hypotheses and conditions rated the frequency of rhythmic movements (e.g., head bobs, rhythmic sways) on a scale of 1 (no rhythmic movements) to 7 (moving rhythmically during the entire trial) and the energy or exuberance of such movements on a scale of 1 (no energy) to 7 (extremely energetic) from silent videos of each nonfussy trial for all 29 mothers. A second naïve rater rated 26% of the clips, with moderate interrater reliability for frequency, $R = .783$, $p < .001$, and energy, $R = .786$, $p < .001$. Mean ratings revealed more frequent rhythmic movements during playful renditions ($M = 4.59$, $SD = 1.25$) than during soothing renditions ($M = 3.28$, $SD = 1.37$), $t(28) = 7.57$, $p < .001$, paired-samples $t$ test. Analysis of movement exuberance was restricted to trials in which maternal gestures occurred. Mothers’ rhythmic movements were significantly more exuberant during playful renditions ($M = 3.41$, $SD = 1.11$) than during soothing renditions ($M = 2.26$, $SD = 0.89$), $t(28) = 9.10$, $p < .001$, paired-samples $t$ test.

Maternal smiling was coded from muted videos during the first nonfussy soothing and playful trial from all 29 mothers. A naïve rater blind to conditions and hypotheses calculated proportion of time spent smiling by mothers during periods of infant maternally directed attention. A second rater, also naïve to condition, rated 24% of the videos, with high interrater reliability, $R = .89$, $p < .001$. Mean proportion of time spent smiling while singing was significantly greater during playful ($M = 0.81$, $SD = 0.35$) compared with soothing renditions, ($M = 0.56$, $SD = 0.44$), $t(28) = 2.23$, $p < .034$, paired samples $t$ test.

### Table 1. Acoustic Features for Each Song Style

<table>
<thead>
<tr>
<th>Feature</th>
<th>Mirtoolbox Details</th>
<th>Lullaby</th>
<th>Playsong</th>
<th>$t(27)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tempo (beats per minute)</td>
<td>mirtempo (“spectrum”)</td>
<td>113 (14)</td>
<td>135 (21)</td>
<td>−6.00*</td>
</tr>
<tr>
<td>Pulse clarity</td>
<td>mirpulseclarity</td>
<td>0.15 (.05)</td>
<td>0.21 (.06)</td>
<td>−6.34*</td>
</tr>
<tr>
<td>Frequency (Hz)</td>
<td>mirtipitch (&lt;400 Hz)</td>
<td>259 (37)</td>
<td>278 (33)</td>
<td>−4.85*</td>
</tr>
<tr>
<td>RMS energy</td>
<td>mirrms</td>
<td>0.04 (.02)</td>
<td>0.07 (.03)</td>
<td>−8.22*</td>
</tr>
</tbody>
</table>

Means ($SD$) are reported, as well as $t$ values for paired-samples tests comparing features across song style.

* $p < .001$. 

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DISCUSSION

Mothers sang *Twinkle, Twinkle, Little Star* to their infant in a soothing or playful style on alternating trials, with maternal and infant SC levels and behavior monitored continuously. The manipulation—asking mothers to sing in a soothing or playful style—was successful in the sense that mothers produced distinctive soothing and playful performances. Their playful renditions were faster, louder, more rhythmic, and higher in pitch than their soothing renditions, which confirms that mothers produce the characteristic performance differences between playsongs and lullabies (Trehub & Trainor, 1998; Trainor et al., 1997) in their contrastive renditions of the same song. Playful renditions also featured more energetic rhythmic movement and smiling, which highlights maternal singing as a multimodal event rather than a mere auditory event (Trehub, 2018).

Infant arousal levels decreased in response to soothing renditions, as did maternal arousal levels despite the absence of holding or rocking that commonly accompanies lullaby singing. Infants’ decreased arousal levels are consistent with the universality of lullabies (Mehr et al., 2018; Trehub & Trainor, 1998) and with their putative role in soothing infants and inducing sleep. The soothing and soporific effects of lullabies would have been critical for infant survival in the harsh environments of the distant past, for example, by conserving infant energy lost to crying (Rao, Blass, Brignol, Marino, & Glass, 1997), decreasing the risk of predation (Barr, 1990), and easing the considerable burdens of caregiving (Zeifman, 2001). Infants’ lesser attention to mother during soothing than during playful renditions reflects some degree of disengagement from the ongoing interaction, which would be necessary for progress toward further arousal reduction and, ultimately, sleep.

Mothers’ decreased arousal levels during soothing singing are consistent with the self-regulatory functions of music, which are relevant to music listening (Pelletier, 2004) as well as singing (Sanal & Gorsev, 2013). The present findings also offer some insight into the means by which singing to infants can reduce maternal depression and anxiety (Fancourt & Perkins, 2018a, 2018b; Arnon et al., 2014). In this study, however, it was not possible to ascertain whether decreased maternal arousal resulted directly from singing in a soothing manner or indirectly from observing its arousal-lowering consequences on infants. Regardless, the findings indicate the efficacy of soothing singing for arousal regulation in parent and infant.

Mothers as well as infants maintained relatively stable arousal levels throughout the episodes of playful singing, in contrast to the decreases in arousal that occurred during episodes of soothing singing. Moreover, infants were more attentive to mother when she sang in a playful rather than soothing manner, reflecting their heightened engagement with her performance. Heightened arousal in mother and infant may have stemmed from the acoustic features (e.g., higher pitch and amplitude, faster tempo, greater pulse clarity), the energetic rhythmic movements and smiling that characterized playful renditions, or some combination of those features.

Rhythmic maternal movements such as these may scaffold the emergence of rhythmic movement to music in infancy (Zentner & Eerola, 2010). Note, however, that synchronized movement to music does not emerge until the preschool years (Drake, Jones, & Baruch, 2000) nor does it become adult-like until about 10 years of age (McAuley, Jones, Holub, Johnston, & Miller, 2006). Rhythmic movement underlies much of the social nature of musical interactions. For example, moving in synchrony with others, which is a common feature of musical interaction, encourages prosociality in infants (Cirelli, 2018; Cirelli et al., 2014) and adults (for a meta-analysis, see Mogan, Fischer, & Bulbulia, 2017). Increased physiological arousal may also facilitate social bonding through the endorphin system (Dunbar et al., 2016). For example, adults feel socially connected to peers after watching a dramatic movie (Dunbar et al., 2016), experiencing pain (Bastian, Jetten, & Ferris, 2014), or performing physically exerting movements with them (Jackson et al., 2018).

To our knowledge, this is the first study to explore maternal and infant arousal in the course of a musical interaction. In previous research, infant SC levels were used to assess the efficacy of maternal song in reducing the arousal of distressed infants (Trehub, Ghazban, & Corbeil, 2015; Ghazban, 2013). Maternal song proved to be more effective than maternal speech for reducing infant distress and arousal, but playsongs were more effective than lullabies in this regard. How can we reconcile the seemingly contradictory outcomes of the earlier study—greater arousal reduction for playsongs than for lullabies (Trehub et al., 2015; Ghazban, 2013)—and this study—arousal reduction for soothing but not for playful renditions? In the previous study, mothers sang to infants following a still-face manipulation that resulted in highly elevated arousal levels in infants as well as overt distress (e.g., negative vocalizations and facial expressions). In the present research, however, infants were seemingly content rather than distressed, and they exhibited greater engagement during playful renditions than during soothing renditions. If playful singing succeeds in engaging distressed or highly aroused infants, it is likely to distract or disengage them from the distressing circumstances, with arousal-lowering consequences (Rothbart, Sheese, Rueda, & Posner, 2011). These studies of the arousal consequences of maternal singing highlight the context-dependent effects of playful and soothing singing.

Songs also convey important social meaning to infants, especially the songs learned from parents (Cirelli et al., 2018; Mehr et al., 2016). For example, 5-month-old infants exhibit greater social engagement with an unfamiliar
woman who sang a familiar melody (i.e., one sung by parents at home) than with another woman who sang an unfamiliar melody (Mehr et al., 2016). By 11 months of age, infants more readily accept an object endorsed by the singer of a familiar song rather than an unfamiliar song (Mehr & Spelke, 2018). By 14 months of age, infants are more willing to help an unfamiliar woman who sings a familiar song than one who sings an unfamiliar song, and the extent of their helpfulness correlates with parents’ frequency of singing that song (Cirelli & Trehub, 2018). Together with the present research, these findings suggest that parent–infant song plays an important role in regulating infant arousal and attention and facilitating social bonding.

In summary, this study revealed that multimodal maternal singing in a soothing style reduces the arousal levels of infants and mothers, in contrast to playful maternal singing, which stabilizes mother–infant arousal and captures infant attention. The findings constitute a first step toward understanding the arousal consequences of singing for mothers and their infant audience. We would expect these consequences to be even more pronounced in naturalistic contexts when parents tailor their song style to infants’ needs. We know that infants’ presence and visibility affect the expressiveness of maternal singing (Trehub et al., 1997, 2016; Trainor, 1996), but do they also affect the arousal consequences of mothers’ soothing and playful singing? As for infants, are the arousal-lowering consequences of soothing singing specific to parental singing or generalizable to unfamiliar singers? Does soothing and playful speech influence maternal and infant arousal in comparable ways? Visual cues enhance infants’ responsiveness to ID songs relative to ID speech (Costa-Giomi & Ilari, 2014; Nakata & Trehub, 2004), but audio recordings of ID song are also more effective than comparable recordings of ID speech in maintaining infants’ composure (Corbeil et al., 2016). It is of interest to ascertain whether audio-only recordings of soothing singing are effective in reducing infant arousal, especially for familiar musical material. If audio material is effective in this regard, one could isolate the cues that underlie the observed effects. These and other questions await further research.

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