


ORIGINAL ARTICLE

Maternal singing reduced pain indexes in 2-month-old infants and increased proximity during vaccinations

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Abstract

Aim: Immunisation is a global health priority, but methods of non-pharmacological pain relief are not widely used in routine clinical practice. In this study, we set out to investigate the effects of maternal singing during the routine vaccination of infants.

Methods: We recruited 67 mother–infant pairs at Health Centres in the Aosta Region of Italy. Infants aged 2–4 months were randomly allocated to a singing intervention group or to a control group whose injections were administered following standard practice. Pre- and post-immunisation pain was blindly assessed using the Modified Behavioural Pain Scale, and mother–infant proximity indexes were assigned based on muted video-tracks.

Results: When assessed for pain, the infants in the maternal singing group were assigned significantly lower movement indexes ($p=0.032$) and marginally significantly lower cry indexes ($p=0.076$). A higher frequency of mother-to-infant gaze ($p<0.005$) was observed in the singing group dyads. Finally, the intervention group mothers' self-perceived ease in singing was correlated with their previous singing experience and with lower anxiety following the vaccination procedure ($p<0.05$).

Conclusion: Maternal singing during immunisation procedures benefits both mothers and babies. The practice of singing is a biologically rooted and adaptive form of intuitive parental communication that should be encouraged, especially in at-risk populations.

KEYWORDS

immunisation, maternal singing, non-pharmacological intervention, pain, proximity

1 | INTRODUCTION

Experiencing physiological and psychosocial stressors in early life has been found to impact a range of later health outcomes, potentially undermining infant well-being.¹ Early pain exposure has been associated with delays in growth, poor neurological development,

high cortical activation and impaired brain development.² Although immunisation is a global health priority, studies have found that pain relief methods are not widely implemented in routine clinical practice. Researchers have called for further investigation and implementation of non-pharmacological and parent-based protective interventions in paediatric clinical practice.³

Abbreviations: ANOVA, analysis of variance; MBPS, modified behavioural pain scale; NICU, neonatal intensive care unit; STAI, state–trait anxiety inventory.

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Past studies have investigated the effects of a combination of sucrose, oral tactile stimulation and parental holding on pain in 2-month-old infants receiving vaccine injections.⁴ Recent years have seen a surge of interest in the efficacy of different methods of neonatal pain management, especially surrounding the validation of non-pharmacological approaches. Among the more common non-pharmacological pain reduction techniques, parent-based interventions such as breastfeeding and skin-to-skin contact have been found to reduce procedural pain⁵ and decrease behavioural and cortical pain responses to heel pricks. In a recent study, pain scores were assigned to 495 newborn infants undergoing venipunctures and preprocedural analgesia. High-pain scores were associated with the absence of parents during the procedures, and the authors concluded that parental presence should be encouraged.⁶

In the present study, we focused on the effects of live maternal singing as a specific form of protective intervention delivered by parents.

Singing to infants is a ubiquitous practice that has been found to display near-universal features, including across non-proximal cultures.⁷ Singing has been observed to sustain infants' attention more effectively than speech. It has also been shown to outperform speech in modulating arousal and reducing the expression of negative affect in infants, thus mitigating infant distress.⁸

In clinical settings, music therapy has been reported to enhance the care of preterm infants by reducing stress and crying,⁹ fostering dyadic interaction¹⁰ and improving physiological stability.¹¹ Developmentally, singing to infants has been found to modulate infants' musical preferences, facilitate language acquisition and foster rich social-communicative interpersonal engagement, which is key to social development.¹² Interestingly for the present study, infant-directed singing not only enhances emotional closeness but also reduces negative affect and cortisol, a marker of distress in infants.¹³ Furthermore, in parents, daily singing to babies has been linked to fewer postnatal depression symptoms, as well as improved health, self-esteem and self-reported mother–infant bonding.¹⁴

More specifically to pain treatment, the mother's live voice has analgesic effects on pain expression in the preterm infant, concomitantly raising oxytocin levels in both infant and mother.¹⁵ Endogenous oxytocin released during mother–infant vocal contact, together with its impact on the maturation of the autonomous nervous system, has been flagged as a potential protective mechanism against pain.

Maternal singing to newborns has been shown to enhance maturation of the autonomic nervous system in preterm infants in the NICU by modulating heart rate variability and activating the parasympathetic system.^{16,17} Infant heart rate variability reliably reflects the gradual maturation of the autonomic nervous system in newborns, which is accompanied by the progressive activation of parasympathetic tone. As the newborn brain develops, the higher cortical processes incorporate autonomic control. It follows that parasympathetic activity dominates autonomic maturation during the first 2 years of life.

Key notes

- Immunisation is a global health priority, but methods of non-pharmacological pain relief are not widely used in routine clinical practice.
- Maternal singing during immunisation procedures benefits both mothers and babies, decreasing pain behaviour indexes in infants and increasing signs of proximity in the dyad.
- Maternal ease in singing is associated with prior singing experience and lower levels of anxiety in mothers during vaccination procedures.

Live maternal singing, with its potential to modulate infant responses, enables parents to respond dynamically to the consolation and protection needs of an infant undergoing a painful procedure.¹⁸

In sum, live parental vocal contact is not mere acoustic stimulation, but rather active, family-centred intervention in infant care, especially during challenging and painful experiences. Two key elements characterise this protective intervention: first, the parental voice, as a unique and salient stimulus for newborns and a privileged medium for sharing emotions, soothing and generally fostering co-regulation within the dyad; and second, the biologically based protection offered by the active presence of a parent.

According to recent research, early vocal contact between parents and infants not only alleviates pain in preterm infants as previously documented but also reduces parental anxiety and boosts parental oxytocin levels.¹⁹

The aim of this study was to assess whether maternal singing during a painful vaccination procedure reduced the expression of pain in 2–4-month infants or increased signs of proximity in the mother–infant dyad. We also set out to investigate whether mothers' prior informal singing experience was associated with their self-perceived ease in singing and levels of anxiety during the vocal intervention.

2 | MATERIALS AND METHODS

2.1 | Participants

Participants in the study were 67 parent–infant dyads recruited at Health Centres across the Aosta Region of Italy. The infants were between 2 and 4 months (39 boys) and were receiving their first routine vaccination injection. Although the protocol was open to both parents, in 100% of the cases the parent attending the procedure was the mother. Mother–infant dyads were only included in the sample if the mother provided written informed consent. Dyads were excluded if the infant had been diagnosed with a chronic disease or described as clinically unstable by the hospital paediatrician.

TABLE 1 Maternal characteristics in the two groups.

Mothers	Singing group	Control group
Age (years)	$m = 31.9$ ($SD = 5.32$)	$m = 33.4$ ($SD = 5.23$)
Citizenship	Italian (96.96%)	Italian (82.35%)
Civil status	Married (42.43%), Other (57.57%)	Married (55.88%), Other (44.12%)
Socio-economic score	Low (6.1%), Medium (72.7%), High (15.2%)	Low (8.8%), Medium (20.6%), High (67.6%)

The study was approved by the Aosta Valley Health Service Ethics Committee (n. 90512, 20/10/2017).

2.2 | Procedure

Participants were preliminarily enrolled in the study via an introductory telephone call, during which they were verbally given the information provided on the written consent form. The data were collected during the infants' first paediatric vaccination session, which was routinely preceded by a screening visit and health assessment. Before the vaccination injection was administered, the healthcare staff offered guidance about the vaccination procedure and a trained researcher once again presented the research project and obtained written consent from the parents.

The trained researcher was a clinical psychologist with expertise in observing early mother–infant interaction. After providing consent, each participating dyad was randomly assigned to either the experimental group, with 33 infants, of whom 19 were boys, or the control group, with 34 infants, of whom 20 were boys.

In the experimental group, parents were asked to start singing 5–15s before the vaccination was administered and to continue singing for 1min afterwards. In the control group, parents were asked to comfort their infant as they would normally do but to avoid singing. In both groups, parents were asked not to use artificial objects to soothe their babies.

In this study, analysis was confined to the first minute following the injection.

The mothers were free to choose what to sing during the intervention and were encouraged to follow their own preferences. We did not conduct any specialised acoustic analysis on the spontaneous maternal singing, given that this was not the main aim of the study, and that the low quality of the recordings did not facilitate accurate acoustic measurements. Rather, we compiled a qualitative profile of the content and style of the mothers' singing. Concerning the contents, lullabies were chosen by 24.3% of the mothers and children's songs by 63.6%, while the remaining 12.1% of singing interventions were not readily classifiable. Furthermore, 87.9% of mothers sang with words, while 9.1% sang without words and 3.0% alternated singing with and without words. All the mothers chose to sing in their native language. Finally, most of the mothers (90.9%) continued to sing the same song before, during and after the immunisation procedure. All the songs were slow in tempo, ranging from 60 to 75 beats per minute. Due to the quality of the audio recordings, exact measures of sound intensity could not be obtained. The mothers' spontaneous

singing styles were divided into two categories: 12.1% of the sample sang in a whisper, while the remaining 87.9% sang in a louder voice. The songs are listed in Table S1.

Routine vaccination practice involves positioning the infant on an examination bed.

During the pre-vaccination phase, either maternal singing or non-singing maternal intervention was provided for a maximum of 15s, in keeping with the standard procedure. At this stage, the mother was asked to restrain the infant's arms and legs to avoid sudden movements during the injection. The vaccination itself was performed rapidly by a physician and a healthcare assistant. The maternal singing or control intervention continued for a minimum of 1min following the injection. The timeline of the procedure is shown in Table S1.

Next, mothers were routinely asked to wait for at least 30min so that the infant's health status following the vaccination could be monitored. During this time, the mothers were asked to complete the study questionnaires. The mothers' demographic characteristics are summarised in Table 1.

2.3 | Video behaviour coding: infant pain and dyadic proximity measures

All the sessions were recorded using a Handycam HDD video camera (Sony, Tokyo, Japan). Recording was initiated 5s before the vaccine was administered and continued for 30s after the immunisation was completed. Muted versions of the videos were independently coded by two trained coders who were blinded to the research conditions.²⁰ Infant pain was assessed using the Modified Behavioural Pain Scale (MBPS),²¹ a multidimensional scale developed in the context of infant immunisation procedures. Three indicators of pain were coded: facial expression, cry and movement. Given that pain during immunisation is known to modify quickly, the recommended observation periods are brief; baseline ratings are obtained 5–15s before the procedure, and postimmunisation values are generated within 15s following the vaccine. The scores range from 0 for absent to 3 for severe for the facial expression and movement indicators and from 0 to 4 for crying. The sum of the scores for the individual indicators yields a global pain intensity score ranging from 0 to 10.

The secondary outcomes of the study concerned the physical proximity between mothers and infants. These were measured before and after the immunisation procedure and comprised the frequency and the duration of four behavioural indicators: rocking, kissing, mother-to-infant gaze and infant-to-mother gaze. A global

score for each indicator was then obtained by weighting occurrences per duration.

2.4 | Maternal questionnaires: maternal anxiety level, ease in singing and singing experience

Maternal anxiety in both groups was measured via the 20-item State-Trait Anxiety Inventory (STAI),²² which the mothers completed both before and after the intervention, yielding Cronbach alpha coefficients of 0.90 and 0.82, respectively. The STAI questionnaire is frequently used in research to predict caregiver distress. In the present study, we only administered the STAI State scale, which is designed to measure how individuals feel at the present moment. We conducted correlational analyses to determine whether there was an association between the STAI scores and the extent to which the mothers felt at ease during the singing intervention.

To assess the mothers' informal singing experience, as opposed to any formal training, we administered four ad hoc items to be rated on 5-point Likert scales. The aim here was to investigate whether music was part of the mothers' everyday lives, whether they believed that music/singing could help to communicate emotions, how often they sang to their child, and whether they thought that singing to their child could make them feel better personally. The mean of the four items was taken as a global indicator of the quality of the mother's singing experience, with a Cronbach's alpha coefficient of 0.76.

Finally, the mothers in the singing group only were asked to assess their ease in singing during the vaccination procedure by rating two further items on a 5-point Likert scale, with a Cronbach's alpha coefficient of 0.75.

2.5 | Data analysis

All statistical analyses were performed using SPSS version 16.0 software (SPSS Inc.). Infant pain was assessed using the MBPS, and three indicators of pain were coded: facial expression, cry and movement. Indicators of proximity were also assessed, and satisfactory inter-coder reliability was obtained by the two expert coders for the first 10 subjects. Inter-coder reliability was evaluated by computing the Pearson correlation coefficient (r) for each of the four proximity indicators. Once interrater reliability had been confirmed, the remaining videos were divided between the two coders.

To identify differences in pain indexes and proximity indicators between groups, a 2 (group, singing and control) \times 2 (time, pre and post) repeated-measures analysis of variance (ANOVA) with one between-subject and one within-subject factor was performed on each indicator, followed by a post hoc with t -test. Statistical significance was set at $p < 0.05$ (two-tailed). Effect size and observed power estimates were taken into account as well as level of significance. Before conducting the repeated-measures ANOVA on the

three individual pain indicators, the global pain score and the four behavioural indicators of mother–infant proximity, we checked for violations of the assumptions of normality and sphericity for each of the dependent variables. If the Mauchly test yielded a significant outcome, indicating that the data did not satisfy the sphericity assumption, the Greenhouse–Geisser test was also performed.

Mean scores and correlations were also calculated for the three maternal questionnaires (Maternal Anxiety, Ease in Singing and Singing Experience).

3 | RESULTS

3.1 | Infant pain scores

Two trained independent coders analysed the entire corpus. Inter-coder reliability was high and was assessed via the Pearson correlation coefficient (r), computed for each indicator individually (facial expression 0.75, cry 0.79, movement 0.70).

A first series of repeated measures ANOVAs was performed on the three MBPS indicators (facial expression, cry and movement) and on the global pain score. Figure 1 shows the patterns of the mean values. A significant effect of time was observed for the three individual pain indicators and for the global pain score (as illustrated in Figure 1A–D, respectively): facial expression ($F_{65,1} = 301.8$, $p < 0.001$, $\eta_p^2 = 0.31$, power = 0.99); cry ($F_{65,1} = 44.1$, $p < 0.001$, $\eta_p^2 = 0.41$, power = 1), movement ($F_{65,1} = 8.1$, $p < 0.01$, $\eta_p^2 = 0.11$, power = 0.89) and global pain score ($F_{65,1} = 5.0$, $p < 0.05$, $\eta_p^2 = 0.79$, power = 0.99). The group \times time interaction was only significant for cry ($F_{65,1} = 4.7$, $p < 0.05$, $\eta_p^2 = 0.07$, power = 0.57), with lower scores at Time 2 in the singing condition.

A series of post hoc with t -test comparing the two groups at Time 1 and Time 2 showed that, following the painful procedure, movement was significantly lower in the intervention group than in the control group (t -test (65) = 2.2, $p = 0.032$). Cry was also rated lower in the intervention group than in the control group, but this effect was only marginally significant (t -test (65) = 1.81, $p = 0.076$).

As illustrated in Figure 1D, global pain was higher following the vaccine injection in both singing and control groups but the increase was less in the singing group. However, a post hoc with paired t -test showed that at Time 2, the difference between groups was only marginally significant (t -test (65) = 1.70, $p = 0.09$).

3.2 | Proximity indicators

Two trained coders independently analysed the first 10 subjects. Inter-judge reliability was high and was assessed via the Pearson correlation coefficient (r), computed individually for each indicator, with values ranging from 0.69 to 0.99. The remaining videos were then divided between the two coders.

Repeated measures ANOVAs were performed separately on the four behavioural indicators of proximity: rocking, kissing,

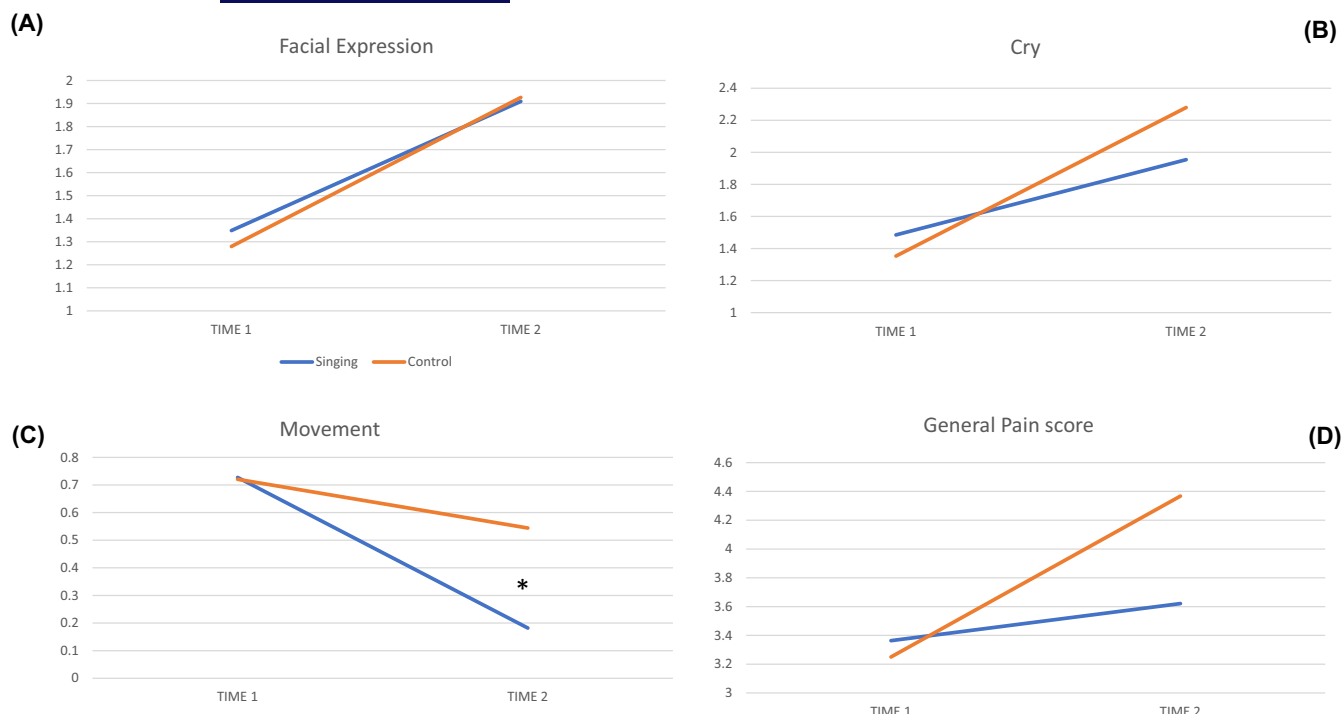


FIGURE 1 Infant pain expression indexes before and after the immunisation procedure. Asterisks denote significant differences between the two groups based on post hoc testing with multiple *t*-tests, with $p < 0.05$.

mother-to-infant gaze, infant-to-mother gaze. The mean values for these measures at Time 1 and Time 2 are represented in Figure 2.

A significant effect of time was observed for rocking ($F_{65,1} = 71.5$, $p < 0.001$, $\eta_p^2 = 0.52$, power = 0.99). Specifically, in both the singing and control groups, rocking was significantly lower pre-vaccination than post-vaccination (Figure 2A). The effect size as indicated by the partial eta squared was large. No significant effects of group, or interaction between group and time, were observed.

No significant effects were observed for kissing, although kissing behaviours increased somewhat at Time 2, following the vaccine injection (Figure 2B).

Similar findings were found for infant-to-mother gaze, although in this case there was a marginally significant effect of time, as illustrated in Figure 2C ($F_{65,1} = 3.3$, $p = 0.078$, $\eta_p^2 = 0.05$, power = 0.42).

Finally, a significant effect of time was observed for mother-to-infant gaze ($F_{65,1} = 45.1$, $p < 0.001$, $\eta_p^2 = 0.41$, power = 1), as well as a significant group \times time interaction ($F_{65,1} = 10.1$, $p < 0.005$, $\eta_p^2 = 0.14$, power = 0.88). As represented in Figure 2, mother-to-infant gaze was more frequent after the intervention in both groups and frequency increased more in the singing group than in the control group.

A post hoc with paired *t*-test confirmed that the frequency of mother-to-infant gaze differed significantly between the singing and control groups post-intervention (t -test(65) = 3.34, $p < 0.001$). Specifically, at Time 2, the singing group mothers gazed at their infants more frequently than the control group mothers, while there had been no significant difference before the intervention.

3.3 | Maternal anxiety levels, ease in singing and singing experience

First, we conducted a descriptive analysis of the variables measured using the maternal questionnaires. Means, standard deviations and correlations are all reported in Table 2.

T-tests yielded no significant differences between the intervention and control groups with respect to the variables presented in Table 2, implying that the two groups were comparable in terms of their anxiety and singing experience.

Furthermore, the correlational analysis showed that the levels of maternal anxiety at the two time points, before and after the injection, as measured via the STAI State scale, were significantly correlated with one another. Finally, singing experience was correlated with self-perceived ease in singing.

To further investigate whether the way mothers felt when singing to their child was associated with their prior musical experience or their level of anxiety, we used a median split to divide the mothers in the intervention group into two groups, based on their relative degree of ease/unease with singing. We then conducted *t*-tests to compare these two subgroups with respect to singing experience, anxiety at Time 1 and anxiety at Time 2. The two groups significantly differed in relation to singing experience and anxiety at Time 2. Mothers who were more at ease with singing displayed lower levels of anxiety at Time 2 ($m = 1.62$, $SD = 0.34$) than mothers who were uneasy about singing ($m = 1.92$, $SD = 0.40$; $t(31) = 2.3$, $p < 0.05$). Mothers who felt comfortable singing also scored higher for self-reported prior singing experience ($m = 4.40$, $SD = 0.69$) than mothers who did not feel

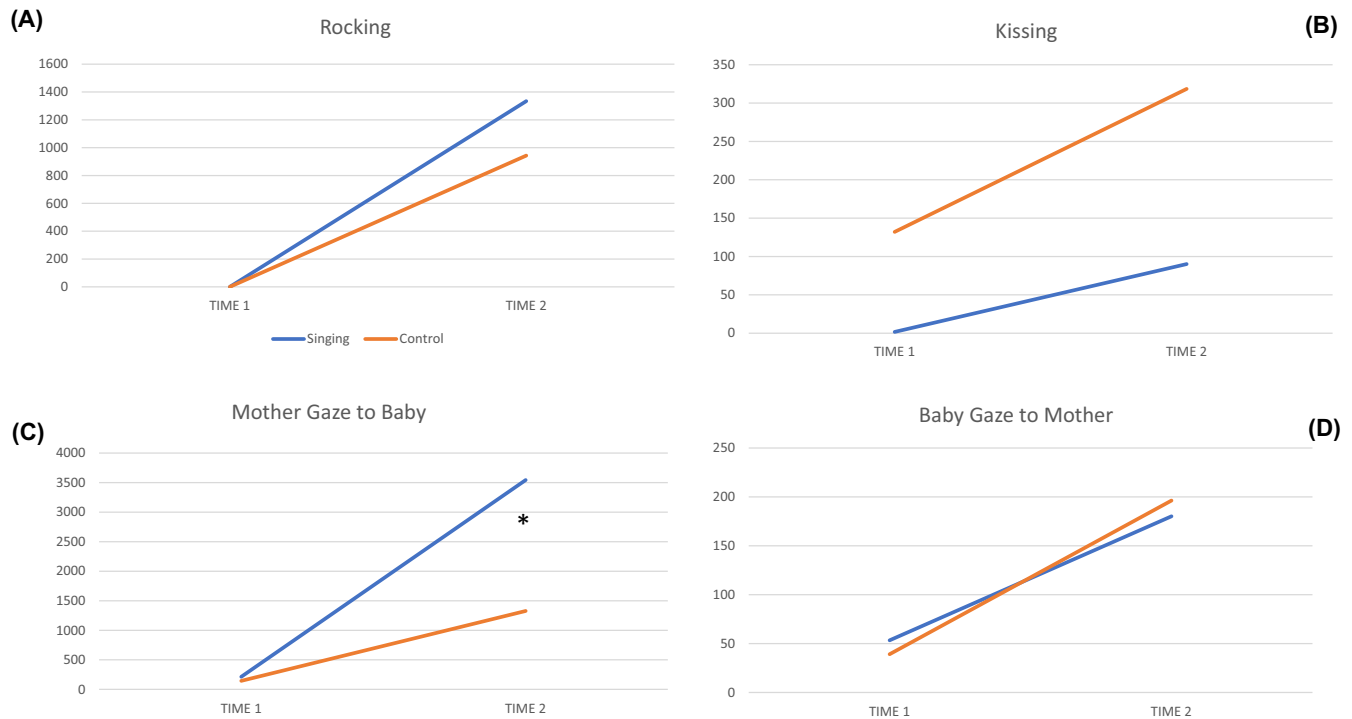


FIGURE 2 Mother–infant proximity indexes before and after the immunisation procedure. Asterisks denote significant differences between the two groups based on post hoc testing with multiple *t*-tests, with $p < 0.05$.

TABLE 2 Correlational and descriptive statistics for the questionnaires administered to the mothers: the anxiety questionnaire (STAI) completed before (Time 1) and after (Time 2) the singing intervention, the Singing Experience questionnaire and the Ease in Singing instrument.

	Mean	SD	STAI at Time 1	STAI at Time 2	Singing experience	Ease in singing
STAI at Time 1	1.81	0.46	–	0.54	–0.24	0.04
STAI at Time 2	1.72	0.34		–	–0.20	0.21
Singing Experience	3.82	0.67			–	0.46
Ease in Singing	2.30	1.02				–

Note: For each variable, means and standard deviations are reported. The correlations between all the variables are reported, with statistically significant correlations in bold.

comfortable ($m = 3.68$, $SD = 0.30$; $t(31) = 4.46$, $p < 0.001$). No significant differences emerged in relation to anxiety at Time 1.

Finally, no adverse events occurred during immunisation, in either the control or singing group.

4 | DISCUSSION

The aim of this study was to examine the potential impact of maternal singing as a parent-based pain relief strategy during the immunisation of infants. To this end, we measured infant pain indexes and indicators of mother–infant proximity, as well as maternal anxiety, prior singing experience, and ease in singing during the intervention.

First, we found that maternal singing reduced infants' pain behaviour indexes, but this effect was only significant for movement and not for crying or facial expression. Both global pain scores and cry scores were lower post-intervention in the singing group, but these decreases were only marginally significant.

These outcomes are partially in line with previous clinical guidelines for pain management in infants during immunisation procedures.²³ Notably, while maternal singing significantly impacted the infants' level of movement, it only marginally reduced their propensity to cry, and had no observable effect on their facial expression of pain. Maternal singing is known to foster emotion regulation, by decreasing the infant's arousal or increasing it during shared play, thus a significant impact on newborn's negative arousal was expected.⁸ The singing intervention in this study may have failed to impact all the pain indicators because the mothers did not have time to establish sufficient closeness with their babies before the vaccination. Building a connection through singing is a gradual process. Thus, mothers may require a longer timeframe to foster a sense of comfort and intimacy via their singing, and thereby alleviate pain during immunisation. Furthermore, young infants tend to adjust their movements to rhythmical stimuli via a process of auditory-motor coordination.²⁴ Thus, it is not surprising that the singing intervention mainly regulated infants' motor expressions of discomfort during the painful procedure.

Second, maternal singing increased the frequency of indicators of proximity during the vaccination procedure. This effect was only statistically significant for mother-to-infant gaze. This is in keeping with earlier findings that infant-directed singing, by any interlocutor and not just by mothers, promotes shared emotional experience within a dyad and within a predictable but flexible structure like a song.⁸ Only partially consistently with our findings, which indicated a one-way increase in mother-to-infant gaze and no mutual increase, infant-directed singing has previously been found to elicit reciprocal social looking between mother and infant, thus habituating infants to the timing of communicative content.¹²

Based on the existing literature, a general increase in signs of proximity was to be expected as a result of the parental singing. However, it may be that an early intervention such as this, which enables parents to actively draw on their intuitive singing abilities during a painful routine vaccination, would need to be better integrated into the vaccination protocol, via dedicated information and time. Albeit in a different clinical setting, with a younger population and in the absence of a painful procedure, numerous studies have micro-analysed the mutual changes between singing mothers and their preterm infants in the NICU: specifically, infants become more communicative and closeness within the dyad is enhanced during singing.²⁵

The biopsychosocial rationales for live parental infant-directed singing to alleviate infant pain during painful procedures have been widely theorised and debated.²⁶ However, additional research is required to identify the exact mechanisms by which maternal singing can protect against infant pain and distress.

Maternal singing has been shown to mitigate some of the adverse effects of pain by fostering positive social interaction and, consequently, dampening the stress response.²⁷ Another possible mechanism by which maternal singing may protect against pain is the modulation of infant heart rate variability. This activates the parasympathetic nervous system in newborn infants, potentially enhancing self-regulation and inhibiting pain.²⁸

Finally, we found that mothers in the intervention group who were comfortable with singing (high levels of perceived ease) reported richer prior singing experience and displayed lower anxiety after the immunisation procedure. At baseline, both intervention and control groups displayed similar levels of anxiety. Ease in singing was positively correlated with past maternal singing experience, suggesting that mothers who already had singing experience were less prone to anxiety following the immunisation procedure.

This last finding was particularly interesting given that anxiety and fear of vaccination are known to be among the main factors underpinning vaccine refusal. Even more importantly, parental anxiety surrounding medical procedures tends to be transmitted to the children, with long-term consequences (including non-participation in health-related prevention campaigns and an ongoing fear of needles).²⁹

Taken together, our findings suggest the importance of encouraging parents to address their infant's distress vocally. Intervention should familiarise parents with the potential of intuitive everyday musical interactions to foster the parent-infant bond. Early protective intervention is particularly recommended for families with mental

health risk and for at-risk populations, including preterm infants exposed to repeated pain and stress from invasive procedures.³⁰

4.1 | Limitations

One limitation of this study was the relatively small sample size and the lack of data concerning the exact age of the participating infants, given that only their age range was recorded.

Another limitation was the lack of acoustic data on the singing repertoire chosen by the mothers. Because the main aim of the study was not to describe the musical characteristics of parents' spontaneous singing, we did not make an audio recording of sufficient quality to support in-depth acoustic analyses. The analysis of tempo in the songs should certainly explore the specific influences of tempo on infant arousal levels. For future research, a time-series analysis could evaluate the dynamic evolution of both melodic and rhythmic features in maternal singing across two correlated time windows, coupled with meticulous behavioural coding of the infant's state and movement patterns. However, it is essential to note that this comprehensive investigation was not the primary objective of our preliminary study on the effects of live directed singing in the context of infant vaccination. Even so, we did compile a qualitative description of the spontaneous singing repertoire in [Table S2](#).

A final limitation was that only parents and infants in optimal health conditions were enrolled in the study. Given that parental singing can benefit families with mental health risk and other at-risk populations, future research should extend the intervention to other groups of participants, such as preterm infants, infants with early detected disabilities, and parents with mental health problems such as early parental depression symptoms.

5 | CONCLUSION

Investigating effective, feasible, low-cost, culturally acceptable and personalisable non-pharmacological strategies for reducing pain and fear of vaccination in infants and older children is key to improving healthcare practices.

This study, together with a growing corpus of related research, suggests that maternal singing may help to protect children against the long-term effects of pain exposure during infancy. Parental singing is a biologically rooted and adaptive form of intuitive musical communication. Singing practices bear the potential to modulate infant arousal and promote interpersonal closeness, even in the face of pain and distress.

AUTHOR CONTRIBUTIONS

Maria Grazia Monaci: Conceptualization; data curation; formal analysis; methodology; writing – review and editing. **Chiara Maria Caruzzo:** Investigation; writing – review and editing. **Romina Raso:** Investigation; writing – review and editing. **Carmen Spagnuolo:** Investigation; writing – review and editing. **Maria Clorinda Benedetti:** Investigation. **Didier Grandjean:** Writing – review and

editing. **Manuela Filippa**: Conceptualization; data curation; methodology; project administration; supervision; writing – original draft; writing – review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

ETHICS STATEMENT

The study complies with the Declaration of Helsinki and was performed according to ethics committee approval (n. 90512, 20/10/2017).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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