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Fathers' and Mothers' Infant Directed Speech Influences Preterm Infant Behavioral State in the NICU

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Abstract

Preterm infants' behavioral state and physiological parameters are affected by environmental noise and adult voices. Only a handful of studies have explored the effects of direct maternal vocal communication on preterm infants' autonomous nervous system responses. Furthermore, to our knowledge, no study to date has investigated the effect of the father's voice on preterm infant's behaviors and physiological parameters. This study evaluated the effects of both mothers' and fathers' infant-directed speech on preterm infants' behavioral states. Fourteen stable, premature infants serving as their own controls were videotaped while their mother and father were speaking to them for 5 min over 2 consecutive days. Infants' behavioral states and state lability were coded for each voice presentation (father and mother), in the three different conditions, before, during, and after the intervention. Present results show an interaction between vocal intervention and infant behavioral state. Both maternal and paternal speech modified infant behavioral state, but no significant difference in the behavioral state distribution was observed between mother's and father's voice presentation. Infants spent more time in a quiet alert state when they heard both voices compared to no vocalization baseline. These findings indicate the importance of both the fathers' and the mothers' voice for preterm infants. The parental vocal intervention has an awakening effect. Further studies are needed to better identify the benefits for preterm infants of a relational care approach.

Keywords Preterm infant · Infant-directed speech · Parent–infant interaction · Behavioral state

Introduction

From an evolutionary developmental perspective, preterm infants are seen as fetuses who develop in extrauterine settings at a vulnerable phase of brain development (McLennan et al. 1983). In the NICU environment, infants receive vital medical care but not the kind of adaptive stimulation that is optimal for cognitive development. They are exposed

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to non-contingent stimuli, such as sudden noises and lights, with some sense being more solicited than others (Cornell and Gottfried 1976). The aim of the present study was to investigate the effects of both mothers' and fathers' infant-directed speech (IDS) on preterm infants' behavioral states in such environment. Because such studies are scarce in the literature, especially regarding fathers, we will first review studies on the effect of exposure to human voices on fetuses and full term newborns, the mechanisms by which early vocal communication can affect preterm infant behavior, and then present the few studies that investigated the effect of mothers' and fathers' IDS on preterm infants.

Auditory Perception in Utero and Fetuses' Reaction to Voices

Fetuses are immersed in a sheltered and complex acoustic environment to which they are responsive (Granier-Deferre et al. 1985; Lecanuet et al. 1988). They receive auditory stimulation from both internal events related to maternal physiology and behavior, such as vocalizations, heart beat and borborygmi (Fifer and Moon 1988), and external sounds attenuated by maternal tissues and fluids (Sohmer and Freeman 2001). By 23–25 weeks gestation, the auditory system is anatomically developed and functional, and we observe fetal reactivity such as changes in heart rate and increase in body movements after external acoustic stimulation (Graven and Browne 2008).

A number of researchers report that fetuses are oriented to their mother's voice, as a special stimulus, both as an internal and an external auditory percept (Querleu et al. 1989; Richards et al. 1992), and that they show specific reactivity to their mother's voice (Marx and Nagy 2015). For example, they can discriminate between maternal and unfamiliar voices (Kisilevsky et al. 2003, 2009); they respond with a decrease in motor activity in the 10 s following the onset of maternal speech (Voegtline et al. 2013) and their physiological and motor responses depend on whether the maternal voice was presented live (increase in cardiac rate) or through an audio recording (cardiac deceleration) (Lee and Kisilevsky 2014). A specific response to the mother voice was also observed at a neurological level in a study using functional magnetic resonance imaging (fMRI) in fetuses (Jardri et al. 2012). This study shows that at 34 weeks gestational age (GA), the lower part of the temporal lobe was significantly more active during exposure to the mother's voice than to an unfamiliar female voice.

Moreover, fetuses can differentiate between male and female voices (Lecanuet et al. 2000), and they react both to the father's and the mother's voices by an increase in heart rate (Lee and Kisilevsky 2014). Another study investigated the effect of the father's voice on fetal heart rate behavior (Kisilevsky et al. 2009). In this study, fetuses showed no change in heart rate at onset of the father's voice, but an increase in heart rate at offset of the voice with a peak at about 30 s before returning to their baseline level of heart rate activity. These results show that fetuses also react to the father's voice, but other studies are clearly needed to test the specificity of this reaction compared to other unfamiliar male voices.

Newborns' Reactions to Mothers' and Fathers' Voices

Newborn infants are attracted to the form of speech that affectionate adults use when speaking to them, involving high pitch, slow tempi, and pitch variability, called infant-directed speech (IDS). A preference for IDS over adult-directed speech is observed until the age of about 9 months (Fernald 1985; Newman and Hussain 2006; Pegg et al. 1992). More generally, full-term newborns actively respond to multimodal infant-directed behavior

(Legerstee 1990) and become distressed with socially unresponsive partners (Nagy et al. 2008).

More specifically, it has been known for a long time that term newborns show a marked preference for the mother's voice over unfamiliar female voices (DeCasper and Fifer 1980; Ockleford et al. 1988). Regarding the effect of the father's voice, term newborns are responsive to their fathers' voice and show, at birth, a similar heart rate increase to maternal and paternal voice presentations (Lee and Kisilevsky 2014). Even though they discriminate between the father's voice and that of other males (DeCasper and Prescott 1984), they show however no preference for the father's voice as late as 4 months-of-age (Ward and Cooper 1999). Do preterm infants possess auditory and responsive capacities that are in continuity with prenatal development and are they similar to those observed in term newborns? In the next paragraphs, we will try to shed light on these questions by reviewing some of the findings on early vocal communication in preterm infants in the NICU.

Preterm Infants' Auditory Perception and Reaction to Voices

Preterm birth involves a sudden separation from the familiar environment of the womb. Despite their atypical brainstem maturation, causing delays in auditory brainstem responses, preterm infants are born with a functional auditory system (Maitre et al. 2017). The brainstem auditory evoked potentials are first recordable between 25 and 27 weeks GA, when the spiral ganglion neurons in the cochlea have established neural connections with the auditory brainstem (Coenraad et al. 2011; Hepper and Shahidullah 1994; Jiang and Chen 2014). The auditory system is sufficiently mature by 30–35 weeks to ensure functional auditory sensitivity, pitch perception, and frequency resolution (Hall 2000). Preterm infants distinguish sounds from background noise at a minimum signal-to-noise ratio of 5–10 A-weighted decibels (dBA) (Kuhn et al. 2012). Moreover, preterm infants react differently to vocal and non-vocal sounds. They significantly decrease their heart rate in response to human voices, whereas their heart rate increases following artificial sound peaks of similar intensities (Kuhn et al. 2017). At 30 weeks postmenstrual age, preterm infants have a lower heart rate after exposure to maternal sounds than after no exposure (Rand and Lahav 2014). At around 34 weeks, they have greater oxygen saturation level and heart rate when the mother is speaking and singing in comparison to periods without maternal vocal stimulation (Filippa et al. 2013). These studies show that preterm infants can perceive their mothers' voice. They can discriminate their mothers' voices from the voices of unfamiliar women, as shown by differences in cortical activation in the right frontal area (Saito et al. 2009). Preterm infants can also respond differently to male and female voices with a decreased heart rate when hearing the male voice (Lee and White-Traut 2014). This is the only study that included fathers, but paternal data were not analyzed separately, so no studies to date have looked at a specific response to the father's voice.

The Effect of Early Vocal Communication on Preterm Infants' Behavioral and Physiological States

Even though preterm infants have a functional auditory system and are responsive to their mother's voice, in the NICU environment they hear their mother's voice much less than in utero (Hofer 2005), and they are deprived of other kinds of natural social stimuli experienced by term newborns such as exposure to faces and social touch (Perlman

2001). Instead, preterm infants are exposed to a variety and density of unfamiliar auditory stimuli (Perlman 2001). These stimuli such as loud, high-frequency, and artificial NICU sounds affect their well-being and disrupt their sleep (Kuhn et al. 2012), and can also have negative short-term effects on their rapidly developing cardiovascular and respiratory systems (Wachman and Lahav 2011). Faced with this situation, experts have started providing guidelines to control the quality of the acoustic environment of the NICU (White 2013). Recent intervention programs are aiming to compensate the dearth of sensitive social interaction between parents and their preterm infants by encouraging forms of "family-centered care", including early vocal communication (Filippa et al. 2017a; Roué et al. 2017).

Given the rapid increase in the variety of voice-based intervention programs in the NICUs, researchers have begun investigating their effects on cohorts of preterm infants' behavioral and physiological responses. Various factors have been investigated, such as the type of voice heard (staff, mothers, music therapists, etc.) or context (speaking, singing, or humming). These studies have provided evidence that hearing human voices is associated with significant short-term (physiological and behavioral) and medium-term (growth and feeding, sleep quality and length of stay) positive outcomes both on physiological and behavioral levels [see Saliba et al. (2018) for a review on the effect of voices other than the mother's]. In most of these studies, the stimuli were mainly recorded singing lullabies sung by unfamiliar individuals.

Other studies evaluated the beneficial effects of the mother's voice on preterm infants [for reviews see Filippa et al. (2017a), Krueger et al. (2010) and Provenzi et al. (2018)]. The included studies showed beneficial short-term effect of maternal voice exposure, both live and recorded, on preterm infant's stability, measured at a physiological level. Other benefits were reported in the nutritional domain and, consequently, on the length of hospital stay (Chorna et al. 2014; Zimmerman et al. 2013). Only one study (Picciolini et al. 2014) demonstrated a long-term positive effect on preterm infants' neurobehavioral development, measured at a neuromotor level, through the general movement analysis.

One of the mechanisms by which early vocal communication affects preterm infant behavior could be that it provides opportunities for preterm infants to exhibit more organized behavior. For example, premature infants exposed to human voices, in general, were found to have better sleep quality (Garunkstiene et al. 2014), to spend more time in an active alert state (Loewy 2015; Loewy et al. 2013), and to show less distress behavior and inconsolable crying (Coleman et al. 1997; Keith et al. 2009). Moreover, some studies find an increase in the frequency of the quiet alert state (Filippa et al. 2013), of eye-opening (Keller et al. 2008), and of attending behaviors and stability (Bozzette 2008) when infants are exposed to their mother's speech.

These findings are considered to be indicative of greater self-regulation to enable social interaction (Als et al. 1994). Furthermore, Early Vocal Contact has been proposed as an early intervention for preterm infants in the NICU (Filippa et al. 2017b). During Early Vocal Contact, the preterm infants' behaviors are affected by the live maternal voice (Filippa et al. 2013) and, reciprocally, the mother's voice regulates the infant's positive behaviors, such as eyes opening or smiles (Filippa et al. 2018). Moreover, Early Vocal Contact enhances the emotional content of the mother's voice (Filippa et al. 2019), which becomes more smiley and more emotional. During these early dyadic exchanges, the mother's vocalizations', in presence of a positive behavior of their infant, show acoustic characteristics more similar to the IDS, such higher pitch and increased intensity variability.

Fathers' Voice and Current Study

Despite the intervention programs focusing on the family and on the importance of parent-infant contact and interaction in the NICU, no study to date has looked at the effect of the father's voice on preterm infants' behavior or developmental outcomes. Yet, in the case of premature birth, the father's ability to take an active part in the care of the infant from the start is often essential (Lindberg et al. 2007). Fathers of premature babies experience parenthood differently from the fathers of term babies with lower involvement and significantly higher psychological stress and depression scores (Deeney et al. 2009). They have been shown to experience high levels of anxiety, frustration, fear, and sadness (Prouhet et al. 2018). However, studies have demonstrated that after the "rollercoaster of emotions" where fathers feel taken aback (Arnold et al. 2013), emotional closeness with the babies is experienced during the NICU hospitalization (Lundqvist et al. 2007). Fathers who held their baby in skin to skin contact describe the experience as an opportunity to be involved in the early care of their baby (Shorey et al. 2016). A recent study showed that paternal affectionate multi-modal stimulation that includes the father's voice plays a central role in evoking the infant's open-eyes and gaze toward the father; and reciprocally, that the infant's alert state with open-eyes oriented toward the father increases the likelihood of paternal affectionate multi-modal communication (Stefana et al. 2019).

In addition, studies have shown that across languages, similar to mothers, fathers use higher mean-f_0, f_0-minimum, and f_0-maximum, greater f_0-variability, shorter utterances, and longer pauses in IDS than in adult-directed speech (Fernald et al. 1989). They also hyper-articulate their vowels when talking to their child (Gergely et al. 2017), and they adapt their prosodic features to the acoustic preferences and emotional needs of their infant (Kokkinaki 2009).

Thus, the aim of this study was to evaluate the behavioral state of preterm newborns in relation to live maternal and paternal speech in the NICU compared to no vocalization baseline conditions. In particular, we expect that fathers' as well as mothers' IDS will be associated with longer time spent in awake states compared to sleep states. We also explore whether infants' behavioral states are similarly regulated by mothers and fathers in terms of state stability during exposure to IDS.

Method

Participants

The study was conducted in a level III Neonatal Intensive Care Unit at Keserwan Medical Center (Ghazir, Lebanon). The Hospital Ethical Committee reviewed and approved the study and written consent signed by the parents was obtained for each infant.

Study selection included infants who were more than 29 weeks GA and/or weighed more than 1000 g at birth. A stable medical condition was required. Infants with congenital anomalies, neurological disorders, receiving palliative care or critically ill, as determined by the neonatologist, were excluded as well as the infants who failed hearing screening on discharge. Moreover, newborns with parents suffering from psychiatric illness or sensory impairment (hearing loss, mutism) were also excluded from the study.

A total of 39 infants were screened between May 2018 and January 2019. Twenty-six infants and their parents met the inclusion criteria and were approached for enrollment: 8 declined to participate in the study, 4 were excluded because of incomplete data, and 14 infants and their parents (mother and father) participated in the study (see Table 1).

Materials

Infants were filmed using a Sony HD camcorder (Sony© Handycam HDD dcr-sr30 and HDD dcr-sr58, Tokyo, Japan) on a tripod. The camera was mounted at the side of the incubator or the crib. Audio data were obtained using a digital portable audio-recorder (ZOOM H4) recorded at 16-bit/44.1 kHz, held by the parent. Decibel levels were measured using the calibrated Velleman sound meter, in low (1 s) response time, and in A-weighting configuration (dBA).

Table 1 Characteristics of the study sample

Study sample characteristics[a]	*n* (%)
Mother	
Mother's age (year) *mean* ± *SD*	32.86 ± 3.78
Father	
Father's age (year) *mean* ± *SD*	36.79 ± 5.32
Pregnancy	
Single	5 (35.7%)
Twin	9 (64.3%)
Delivery data	
Reason	
Premature contraction	12 (85.7%)
Other	2 (14.3%)
Delivery type	
Caesarean section	14 (100%)
Infant	
Gender	
Male	6 (42.9%)
Female	8 (57.1%)
Gestational age at birth (week) *mean* ± *SD*	31.7 ± 1.99
Gestational age at enrolment (week) *mean* ± *SD*	34.7 ± 1.03
Birth weight (g) *mean* ± *SD*	1634 ± 385
Weight at enrolment (g) *mean* ± *SD*	1980 ± 295
Apgar score	
At 1 min (points) *mean* ± *SD*	7.86 ± .66
At 5 min (points) *mean* ± *SD*	8.71 ± .47

[a]Continuous and categorical variables are presented as mean ± *SD* and *n* (%), respectively

Procedure

After signing informed consent, mothers and fathers, (in turn) were asked to talk freely to their infant over a 5-min period. Parents were free to choose the content and style of their speech.

They were asked to be as close as possible to the infant's head (face in front of the open door of the incubator or 10 cm from the infant's head if she/he was in an open crib), but to refrain from touching the infant. Data were collected over 2 consecutive days for a total of 2 sessions of 15 min each for each infant. Each 15 min of data collection involved 5 min of no vocalization baseline measures in regular NICU environment during which parents were not present and no direct speech was addressed to the baby (baseline condition), followed by the 5 min live speech in which one parent (father or mother) was asked to speak to the infant the first day and the other parent was asked to speak the second day with a counterbalanced order (intervention condition), and followed by 5 min of no vocalization post-intervention measures similar to the no vocalization baseline condition (post-intervention condition). All the sessions were consecutively sampled in time. Sessions were scheduled for each session approximately 30 min prior to planned nursing care. This time frame was chosen to avoid disturbing the infant's rest, to minimize inconvenience to the nursing staff, and to capture a period when the infant is more likely to be awake. Recording sessions occurred in the afternoon between 5 and 6 pm due to parents' work commitments. Infants were tested in their hospital room and in their individual incubators. Sessions began when infants were in an active sleep. The sound level in the NICU room ranged from 48.8 to 60.5 dBA, and the room was for one to three infants. Parents were asked to raise their voices 10 dBA above background noise levels (monitored by the sound meter). The sound level, ranged from 61.8 to 70.2 dBA and from 59.7 to 70.9 dBA, respectively, for mothers' and fathers' conditions.

Measures

Behavioral States

Behavioral states were coded according to the Neonatal Behavioral Assessment Scale (NBAS) (Als et al. 2004).

Deep Sleep (1) Regular breathing/Eyes closed/No spontaneous activity/No eye movements/External stimuli produce startles with some delay.

Active Sleep (2) Eyes closed/Rapid eye movements can be observed under closed lids/Low activity level with random movements and startles or startle equivalents/Responds to internal and external stimuli with startle equivalents/Respirations are irregular/Sucking movements can occur on and off/Eye opening may occur briefly at intervals.

Drowsy (3) Eyes may be open but dull and heavy-lidded or closed/Eyelids fluttering/Activity level variable/Mild startles from time to time/Reactive to sensory stimuli, but response often delayed/Movement are usually smooth/Dazed look when the infant is not processing information and is not fully alert.

Quiet Awake (4) Bright look/Seems to focus attention on source of stimulation and appears to process information actively and with modulation/Motor activity is at a minimum/Kind of glazed look which can be easily broken through in this state.

Active Awake (5) Eyes open/Considerable motor activity with trusting movements of the extremities and even a few spontaneous startles/Reactive to external stimulation with increase in startles or motor activity/Brief fussy vocalizations.

Crying (6) Intense crying/Motor activity is high.

As behavioral states were mutually exclusive, the onset of a state corresponds to the first frame during which the state was perceived as changing, and the offset was thus defined by the first frame of the next change of state. For each of the three conditions (baseline, intervention, and post-intervention), state durations were extracted and converted to percentages by calculating the total time a premature infant spent in a given state as a proportion of the total duration. Moreover, in the intervention condition, percentages of time spent in each state were computed separately for mother and father. We also computed the number of behavioral state changes in a lability scores.

The research videotapes were transcribed and analyzed in a blinded fashion by two trained independent raters using the ELAN (EUDICO Linguistic Annotator) software. This tool allows elaborate coding schemes and accurate event timing and generates results involving statistical analysis. The inter-rater reliability (Cohen's kappa) was .978 for the infants' behavioral state.

Statistics

All analyses were performed using Stata for Windows (version 14; StataCorp). States percentages and lability scores were each analyzed as a function of condition and as a function of partner using a general linear model including GA at birth and at enrollment, birthweight, and gender as potential confounds.

Results

Effect of Live Maternal and Paternal IDS on Preterm Infants' Behavioral States

We first examined the time spent in each behavioral state as a function of the three different sequences: no vocalization baseline, intervention, and post-intervention. Six behavioral levels were distinguished: deep sleep (DS), active sleep (AS), drowsiness (D), quiet alert (QA), active alert state (AA) and crying state (CS).

Distribution of behavioral states according to conditions is presented in Table 2. From baseline to intervention condition, we observed an overall decrease in deep sleep, active sleep, and drowsy states in favor of more quiet and active awake states. Statistical analyses conducted on each state revealed a significant increase of percentage of time spent in quiet awake state (adjusted p value = .030) and in active awake state (adjusted p value = .019), and a closed to significant decrease of active sleep (adjusted p value = .055).

In comparison to baseline, the post-intervention condition is characterized by a decrease in active sleep and awake states, but the main change observed was a significant increase in the time spent in deep sleep (adjusted p value = .011).

Table 2 Distribution of behavioral states (in percentages of time) according to conditions

	1	2	3	1 versus 2		1 versus 3	
	Baseline (%)	Intervention (%)	Post-intervention (%)	Unadjusted *p* value	Adjusted[a] *p* value	Unadjusted *p* value	Adjusted[a] *p* value
Deep sleep (1)	5.8	3.6	17.7	.736	.741	.127	.136
Active sleep (2)	64.4	45.4	38.6	.049	.055	.009	.011
Drowsy (3)	28.1	25.8	28.0	.777	.784	*na*	*na*
Quiet awake (4)	.9	16.2	11.9	.029	.030	.112	.114
Active awake (5)	.8	8.7	5.3	.016	.019	.155	.155
Crying (6)[b]	.0	.4	.2				

[a]Adjusted on gestational age at birth and at enrollment, birthweight at birth, and at enrollment and gender

[b]Crying state was not compared across conditions because all six states sum at 100%

Differences in Infant Alertness Between Mothers' and Fathers' IDS

The purpose of this study was also to see whether mothers' and fathers' IDS differently influences preterm infant behavioral state. Although some differences were observed in both distributions (see Table 3), no significant differences were found.

State Lability

The mean number of state changes observed decreased from 3.5 in baseline condition to 3.1 in intervention condition and 3 in post-intervention condition, but no significant effect was found (adjusted *p* values = .413 and .334). Mothers' lability scores were higher than fathers' but not significantly so (3.6 vs. 2.5 with fathers; adjusted *p* value = .087).

Table 3 Distribution of behavioral states (in percentages of time) according to the parent present during the intervention condition

	Mother (%)	Father (%)	Unadjusted *p* value	Adjusted[a] *p* value
Deep sleep (1)	7.1	.0	.327	.292
Active sleep (2)	42.1	48.6	.671	.691
Drowsy (3)	19.0	32.7	.129	.099
Quiet awake (4)	23.2	9.3	.173	.200
Active awake (5)	7.8	9.6	.730	.752
Crying[b] (6)	.8	.0		

[a]Adjusted on gestational age at birth and at enrollment, birthweight at birth, and at enrollment and gender

[b]Crying state was not compared across parents because all six states sum at 100%

Discussion

The purpose of this study was to examine the effect of live maternal and paternal IDS on preterm infants' behavioral state. We expected that hearing their mother or father speaking to them would induce more alertness in preterm infants compared to no vocalization baselines. We explored possible differences in terms of state regulation between mothers' and father's IDS effects.

The results showed that both maternal and paternal speech was associated with a change in infant behavioral state in favor of greater alertness. Indeed, we found significant changes in state from baseline to intervention conditions with infants presenting more awake states in the intervention phase with both parents, and from baseline to post-intervention with an increase in time spent in deep sleep in the post-intervention condition. We also found a statistical tendency for infants to change state more frequently in the mother condition compared to the father condition.

Our results show that preterm infants are sensitive to both paternal and maternal IDS. Given the special status of the mothers' voice (continuously heard in utero both internally and externally), one could expect a difference in responsiveness to the mothers' and fathers' voices. One study compared female and male voices, including fathers, and showed that infants as young as 32 and 35 weeks GA responded differentially to male voices, showing decreased heart rate, which can be interpreted as an attention (orientation) response (Lee and White-Traut 2014). Another recent study showed that paternal multi-modal stimulation increased the likelihood of infant alert state with open-eyes and gazing toward the father (Stefana et al. 2019). However, our study is the first to test the specific effect of the father's voice on preterm infants' behavioral state, and it does not show any difference between mothers and fathers. This result is concordant with previous studies showing that exposure to human voices influences infants as revealed by changes in physiological parameters and behavioral states (Best et al. 2018; Saliba et al. 2018). Indeed, recent studies show that preterm infants are sensitive to the mothers' voice, but also to other voices such as unfamiliar therapists or even experimenters. Therefore, it is not surprising to also find a significant effect of the fathers' voice, particularly give than fathers use IDS with infants in the same way that mothers do (Fernald et al. 1989). Thus, our study does not rule out the possibility that preterm infants are similarly responsive to all exposure to all live voices. Further studies are needed to test this hypothesis by systematically comparing IDS and ADS with mothers, fathers, and unfamiliar speakers. In addition, two confounding factors need to be disentangled in future studies, namely the effects of IDS and the presence of the person nearby. Because in our baseline and post-intervention conditions, the parent was not present, our study does not allow for this distinction.

The increase in alert states during intervention compared to baseline found in the present study supports Bozzette's (2008), Filippa et al.'s (2013) and Keller et al.'s (2008) findings, in which preterm infants exhibited awake states, bright eyes, and controlled motor tone during exposure to maternal vocal stimulation. Loewy (2015) also suggested that vocal familiarity can strengthen positive quiet alert states. This study thus confirms that exposure to mothers as well as to fathers stimulates hospitalized preterm infants. However, over-stimulation is an important risk for preterm infants and further studies are needed to assess specific conditions in which IDS may not be an optimal stimulus for preterm neuro-development. Adapted and regulated early vocal communication seems to provide opportunities for preterm infants to exhibit more organized behavior. The quiet alert states' duration and frequency increase, as shown in the present results, are generally considered to be indicative of greater self-regulation and to enable social interaction which, in the long term, improves the quality of bonding between a parent and a preterm infant (Als and McAnulty 2011). Quiet alertness is a state that allows the preterm infant to respond to the environment in an organized manner (Als et al. 1994).

When we looked at the behavioral state distribution, we also found a significant difference between baseline and post-intervention periods. The post-intervention condition was characterized by a decrease in active sleep and awake states. This can suggest that listening to mothers' and fathers' voices had a soothing effect, as shown in the studies of Bozzette (2008) and Loewy et al. (2013). Furthermore, since light sleep, drowsy, and quiet alert states were much more prevalent than active awake and crying states during intervention and post-intervention, we can argue that infants exhibited more overall energy conservation and organized behaviors (Als and McAnulty 2011). As agitation and crying were rarely observed, it appears that listening to voices (in our case their mother's and father's voices) was not distressing for the premature infants. Positive experiences are essential for healthy neurological development. Appropriate infant stimulation, paired with physiological stabilization, enhances physiological and neurobehavioral development (Hodgson et al. 2007; Merenstein and Gardner 2006).

Lastly, a tendency was observed regarding lability of states: w.hen the mother speaks, infants alternate between sleep and awake states through all intermediate phases, without disorganizing into active awake or crying states. When the father speaks, on the other hand, infants do not frequently change states and mostly stay in a quiet alert state. Preterm infants show habituation behaviors from 33 weeks GA (Lejeune et al. 2019) and it's thus arguable that in the present study infants respond to the familiarity of the mothers' voice more than to their fathers' and present sequences of sleep showing a form of habituation to the voice. Because the voice is less familiar in the father condition than the mother condition, this maintains infants' alert state for longer. The number of infants in our study is probably too small to observe a significant effect of lability; it would be interesting to further investigate this variable in future studies. Another limitation of the study is related to individual differences: because we wanted to ensure an ecological framework for the vocal intervention, parents were asked to talk freely to their infant, which may have resulted in different speech styles and amounts of speech experienced by the infant used between participants. Unfortunately, this could not be measured in this study but should be investigated in further research. The GA group could also be seen as another limitation of our study. A narrower GA range may have led to better comprehension of the developmental factors and the clinical outcomes.

Conclusions

Als et al. (1986) suggests that because preterm infants are more poorly organized, more sensitive and reactive to social/environmental stimulation, and more generally stressed and overstimulated, any interaction with preterm infants should be supportive of their ability to deal with sensory/social stimulation. Vocal stimulation may play a key role in how preterm infants develop a social responsiveness recognized as important for the development of attachment bonds and likely important for neuro-cognitive development.

Using semi-naturalistic IDS thus has the potential to promote infant responsiveness and communicative competence. It should be further refined and tested with larger samples of premature infants with different GA ranges. It may also be interesting to explore more prolonged exposure to parents' IDS. Future studies should also explore more specifically the effects the father's voice might have, compared to the mother's, on physiological parameters and long term outcomes, such as language development and quality of attachment.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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