

Mothers and infants and communicative musicality

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• ABSTRACT

Using music as a model, mother/infant vocalisations are examined using computer-based acoustic analysis. Past research is summarised which demonstrates the importance of both parties in the mother-infant dyad. Methods are then introduced for analysing pulse, quality and narrative in mother/infant vocalisations. These three elements comprise "communicative musicality": those attributes of human communication, which are particularly exploited in music, that allow co-ordinated companionship to arise. The analysis of pulse is based on spectrographic analysis, and regular timing intervals are discovered that serve to co-ordinate the mother's and infant's joint vocalisations. Quality consists of both the pitch-contour of the vocalisations, and their timbre. Pitch plots are derived using software developed for this project using a constant Q spectral transform. I examine how the infant and mother structure their joint exploration of pitch space on the small and large scale. Timbre is measured with a variety of acoustic measures — trstimulus values, sharpness, roughness and width. It is found that the mother's voice changes its quality in response to the infant's. Narrative combines pulse and quality — it allows two persons to share a sense of passing time — and the musical companionship is examined that is created between a mother and her baby as she chants a nursery rhyme. It is concluded that communicative musicality is vital for companionable parent/infant communication.

1

INTRODUCTION

A mother and her young baby are playfully interacting. We hear the mother speak in short bursts, talking in an inviting sing-song manner, and the baby occasionally "answers back". It appears that communication is taking place, but communication based in what? The baby cannot understand the meaning of the words the mother is using, and the baby often answers in "gliding-type" sounds. The communication must be "held" by means other than lexical meaning, grammar and syntax.

Infants usually stimulate an affectionate adult, male or female, to extended poetic or musical speech, which often moves into wordless song, or imitative, rhythmic and repetitive nonsense sounds. This distinctive style of adult speech is called “motherese”, “parentese”, or “infant directed speech” (IDS), and is attended to and responded to with much pleasure by infants. It varies with the age and state, and motives and emotions of the infant partner (Fernald, 1992; Papoušek, M., 1992; Stern *et al.*, 1985).

Experimental studies of infants’ reactions to different elements of human expression have revealed that infants possess complex endowments for perceiving and stimulating parental communicative signals. It has been shown that infants can discriminate timing patterns, pitch, loudness, harmonic interval and voice quality (Trehub, Trainor and Unyk, 1993). An infant can learn its mother’s voice from before birth, and can recognise melodies or poetic verses that were presented for it to hear prenatally (DeCasper and Fifer, 1980; Fifer and Moon, 1995; Hepper, 1995). Reactions of newborns to the human voice and their imitations of facial expressions, vocalisations and hand movements, show that their awareness of human signals, while slow and rudimentary, is already comprehensive, multimodal and coherent at birth (Nadel and Butterworth, 1999). In fact, in the first few months, infants’ face movements and hand gestures are similar in form and timing to the unconscious expressions that accompany speech in conversation between adults, and the hand gestures of newborns can be entrained to the rhythms of adult speech (Condon and Sander, 1974; Fogel and Hannan, 1985; Weinberg and Tronick, 1994; Trevarthen, 1986).

Complementary research on mothers’ expressions when they are addressing their infants shows that the mother/infant pair involves special abilities on both sides. Mothers’ speech to infants has unconscious or intuitive forms that have many of the same characteristics in many different languages. For example, while Mandarin Chinese is intonationally a highly inflected language and American English is not, it has been shown that mothers in both cultures speak in closely matching IDS (Greiser and Kuhl, 1988). The tone of a mother’s voice (the “voice quality”), and its rhythms and melody, are all regulated in predictable ways, and these features match the demonstrated preferences that young infants seek in a human partner (Trehub and Trainor, 1993). Typically, mothers repeat short, evenly spaced words with simple, sing-song intonations in a resonant yet relaxed and “breathy” moderately high-pitched voice (Stern *et al.*, 1982). Baby and mother listen to one another’s sounds, creating co-operative patterns of vocalisations. Micro-analyses of these vocalisations, and of the accompanying gestural movements, have shown that mother/infant behaviour can generate a coherent system which is constrained by matching rhythmic and emotional factors in the two subjects (Beebe, Stern and Jaffe, 1979; Fogel and Thelen, 1987; Murray and Trevarthen, 1985; Stern, 1985; Trevarthen *et al.*, 1981; Tronick and Weinberg, 1997). Indeed, in optimal “proto-

conversations”, expressive phrases are precisely alternated or synchronised between the infant and the adult (Beebe *et al.*, 1985; Jaffe *et al.*, 1973; Tronick *et al.*, 1980). It appears that the mother’s intuitive behaviour supports the infant’s innate communicative capacities (Papoušek and Bornstein, 1992; Papoušek and Papoušek, 1987; Stern *et al.*, 1985).

3

THE QUESTION

While mother/infant interactions have often been perceived as “musical”, there is currently very little discussion or data on the precise similarities between IDS and what we generally understand to be music. What is musical about infant/parent communication? The remainder of this paper will examine the musical nature of IDS, and describe the methods that we have used to draw-out this information.

4

THE METHODS AND THE FINDINGS

When mothers and babies communicate effectively, it is clear that each is highly “attuned” to the vocal and physical gestures of the other. This attunement is critical. Without it, as can occur in an interpersonal disorder such as maternal post-natal depression (Beebe and Lachmann, 1994; Bettes, 1988; Murray and Stein, 1989; Murray *et al.*, 1996; Papoušek and Papoušek, 1997), or sensory and motor disorders of the infant (Burford and Trevarthen, 1997; Fraiberg, 1979; Hauge and Hallan Tønsberg, 1996; Preisler and Palmer, 1986; Trevarthen and Burford, 1995), both parties will suffer. Failed attunement has been demonstrated in perturbation experiments, in which, for example, the mother is asked to keep a still face and to remain silent in front of her infant for one minute. The baby protests (Tronick *et al.*, 1980; Murray and Trevarthen, 1985). In another important test, communication by video was used (Murray and Trevarthen, 1985). First, a mother and her two-month-old infant were set up to interact by means of a video-sound link in which each was photographed by a hidden camera and each saw the other as a video image in real time. A recording of the mother’s behaviour when she was communicating happily with her infant “live” was replayed to the baby. The infant’s immediate reaction to the active but unresponsive replay of the mother was to make signs of protest, and then to withdraw. This experiment demonstrates how vital it is that an infant receive vocal and gestural responses that fit with its innate predisposition to interact with an other. An infant seeks not just encouraging communicative forms of signal from its mother — the signals must be appropriately timed and inflected (Nadel *et al.*, 1999).

The elements of the co-operative and co-dependent communicative interactions between mother and infant combine to make-up what I have called “Communicative Musicality”. This term recognises that the mother and her infant

are partners in a musical dialogue. Communicative musicality consists of the elements pulse, quality and narrative — those attributes of human communication, which are particularly exploited in music, that allow co-ordinated companionship to arise.

4.1.

Pulse is the regular succession of expressive “events” through time. An event in vocal expression may be the beginning or end of a vocalisation, a louder moment, a turn in the pitch-shape of the mother’s voice. The most direct way to measure pulse is through examination of a spectrograph of the mother/infant vocal interaction.

A spectrograph shows the beginning and end of the vocalisations, their general pitch movement, and the amplitude of the vocalisations through time. Figure 1 is a spectrographic analysis of Laura, a 6-week old infant, and her mother vocalising together¹. The vocalisations are represented by their harmonic components, the amplitudes of which are indicated by a grey-scale, calibrated as shown on the top-left on the spectrograph. The mothers words are shown at the bottom of the spectrograph, and the baby’s vocalisations are enclosed by rectangles. The vocalisations are numbered below the spectrograph to allow other measures, which will be introduced later in the paper, to be matched with the spectrograph. The infant’s vocalisations are numbered in *italics*. There are three ten-second sections, each overlapping the other by one or two seconds, as indicated. The pitch-level of C4 (middle-C) is shown by a broken horizontal line².

(1) This recording was made in 1979, in Prof. Trevarthen's laboratory at the University of Edinburgh, during a project entitled “Co-operative understanding in infancy”, funded by the Spencer Foundation of Chicago. Mother and infant were seated in a room by themselves. The infant was comfortably seated and strapped into a seat, so that its limb movements were free and it was able to have eye contact with the mother. During the section shown in the spectrographic analysis, the mother was instructed to freely chat and play with the infant, and to encourage the infant to smile. The overall length of this “treatment” was around three minutes.

Simultaneous video, audio and still photographs were recorded. The mother and infant each had an AKG C451E directional microphone pointing towards their mouth at a distance of around 30 cm. The audio was recorded in stereo onto a Uher 4200 “Report” Stereo reel-to-reel tape-recorder, using 19cm/sec tape speed.

(2) The generation of spectrographs for all mother/infant interactions discussed in this paper proceeded as follows: The audio recording was transferred to the hard disk of a DECpc 425i computer (CPU i486DX2 - 50MHz) using software and sound cards designed by *Digital Audio Labs* (*The EdDitor* vs. 2.31, *Waveform Editor* and *Catalogue Manager*; *The CardD* sound card, sampling at 16 bits, at 44.1 kHz). The sound file was converted from stereo to mono by averaging between the two channels — separation between the two channels was not sufficient for any benefit to be gained from separate spectrographic display. The sound file was then acquired by the Digital Signal Processing package *Hypersignal Workstation v2.02* (manufactured by Hyperception), where a Fast Fourier Transform (FFT) was executed on the waveform file, and the resultant data on frequency displayed as a spectrograph. The phase information was discarded.

The FFT parameters were: Transform size: 4096; Overlap: 2048; Window: Hamming. These parameters were chosen to provide optimum time and frequency resolution within the constraints of the software.

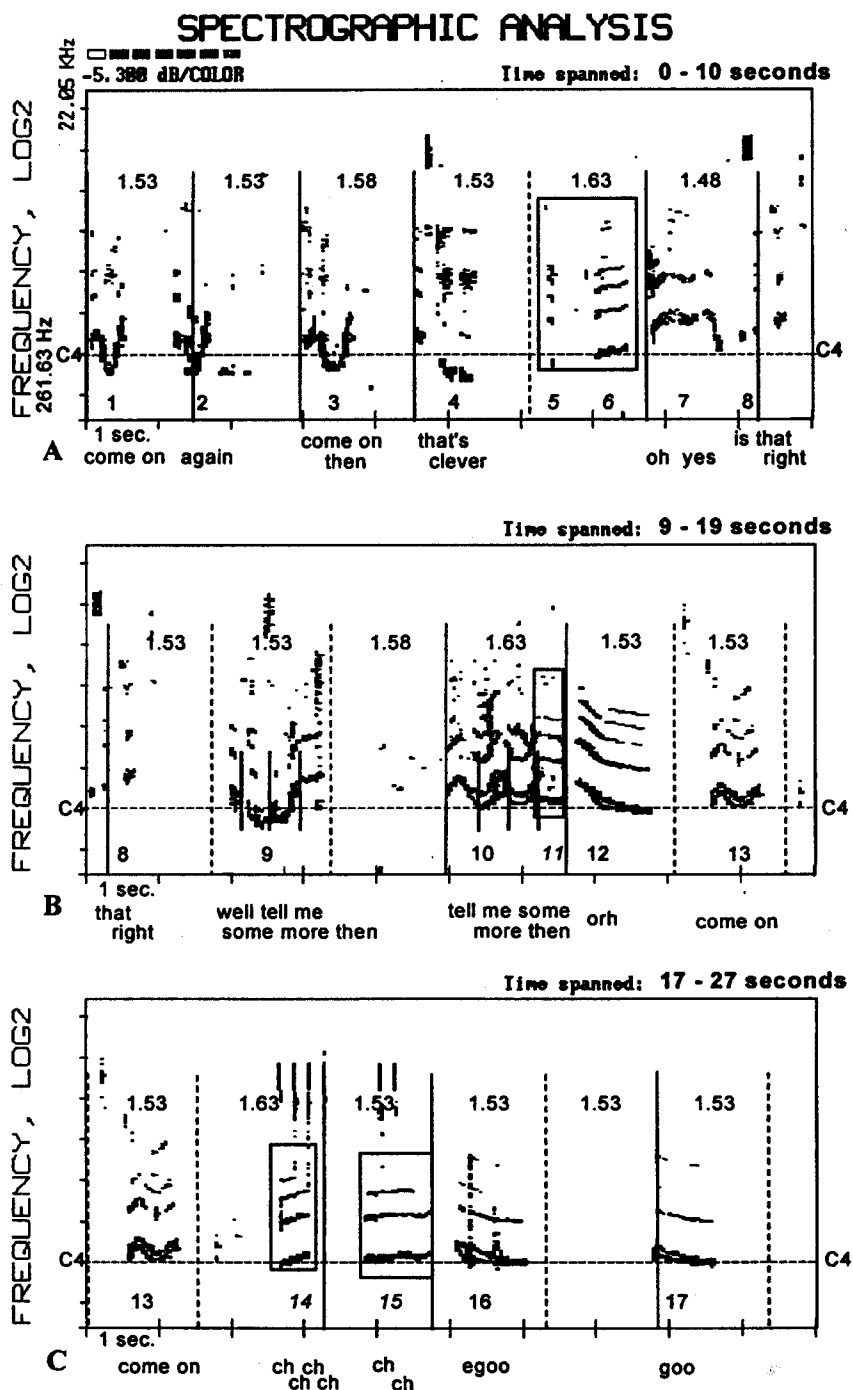


Figure 1. Laura (6 weeks) and her mother vocalising together.

The interpretation of the timing of this vocal exchange is shown by the placement of vertical “bar-lines”. The time-interval between each bar is indicated on the spectrograph in seconds. These bar-lines correspond to important temporal landmarks that occur during the course of the mother/infant interaction. In the first ten seconds, the 1st, 3rd, 4th and 6th bar-lines (the 1st bar-line is against the left edge of the spectrograph) occur at the onset of an utterance; the 2nd bar-line occurs at the lowest part of a pitch bend, and the last bar-line of spectrograph A occurs at an emphasised word (“is *that* right”). The dashed-line bar-lines seen during the thirty seconds occur between events — the time-interval being taken from the most common bar-length in this thirty second interaction. The dashed-line bar-lines enclose a phrase whose beginning and ending fall within the bar, but do not define the limits of the bar. Often, the mother allows timed-space for the infant to reply — for instance, bar 5 in spectrograph A, and the 3rd bar of spectrograph B (though the infant does not vocalise during this opportunity). The infant and mother also demonstrate very accurate small-scale timings. Note how the infant vocalises at the end of the fourth bar of spectrograph B during an interval equal to almost precisely a quarter of the total length of this bar, and, during the whole of this bar, the pitch-curve of the mother’s voice can be divided naturally by this same interval. This is shown on the spectrograph by four equally-spaced vertical lines (the interval between each is 0.41 second). Equality of division in the mother’s vocalisations is also seen in the second full bar of spectrograph B (the interval between each line is 0.38 second). The pitch-curve of the phrase, “tell me some more then” is more rhythmically marked and at a higher pitch in the second utterance, number 10, when compared with utterance 9, perhaps indicating greater “engagement” on the part of the mother, encouraging her baby to join in. In spectrograph C, the clicking sounds that the mother makes with her tongue fall into regular groups, again as shown on the spectrograph by equal-spaced vertical lines. These are spaced at 0.2 seconds — that is, the clicks are uttered at twice the rate of the sub-divisions marked in spectrograph B. Overall, the bars show a remarkable regularity, and the whole interaction shows that the mother and infant enter into co-ordinated, negotiated communication³.

An alternative method of barring mother/infant vocalisations is shown in Figure 2.

These are spectrographs of Sarah, who is 12 weeks old and correspondingly more vigorous than Laura, vocalising together with her mother⁴. Unlike Figure 1, these spectrographs do not overlap. Here, a smaller basic time unit is shown which fits to

(3) The periodicity of this bar-structure is further demonstrated from the results of performing a 4k FFT on the loudness data of this 30 second excerpt. The results show that the highest spike lies at around 0.3 s^{-1} , with a lesser spike around 0.6 s^{-1} . This demonstrates periodicities of around 3.3 and 1.6 seconds. Given the non-exact nature of the bar structure, and that the bar-lines sometimes lie *between* events, this result further strengthens our initial belief of a bar-structure of approximately 1.53 seconds — evidence of a regularity that allows the mother and infant to negotiate their turn-taking.

(4) Recorded under the same circumstances and conditions as described in note 1.

the length of mother's and infant's utterances, and is a subdivision of the longer time units that can be discerned in this thirty second extract.

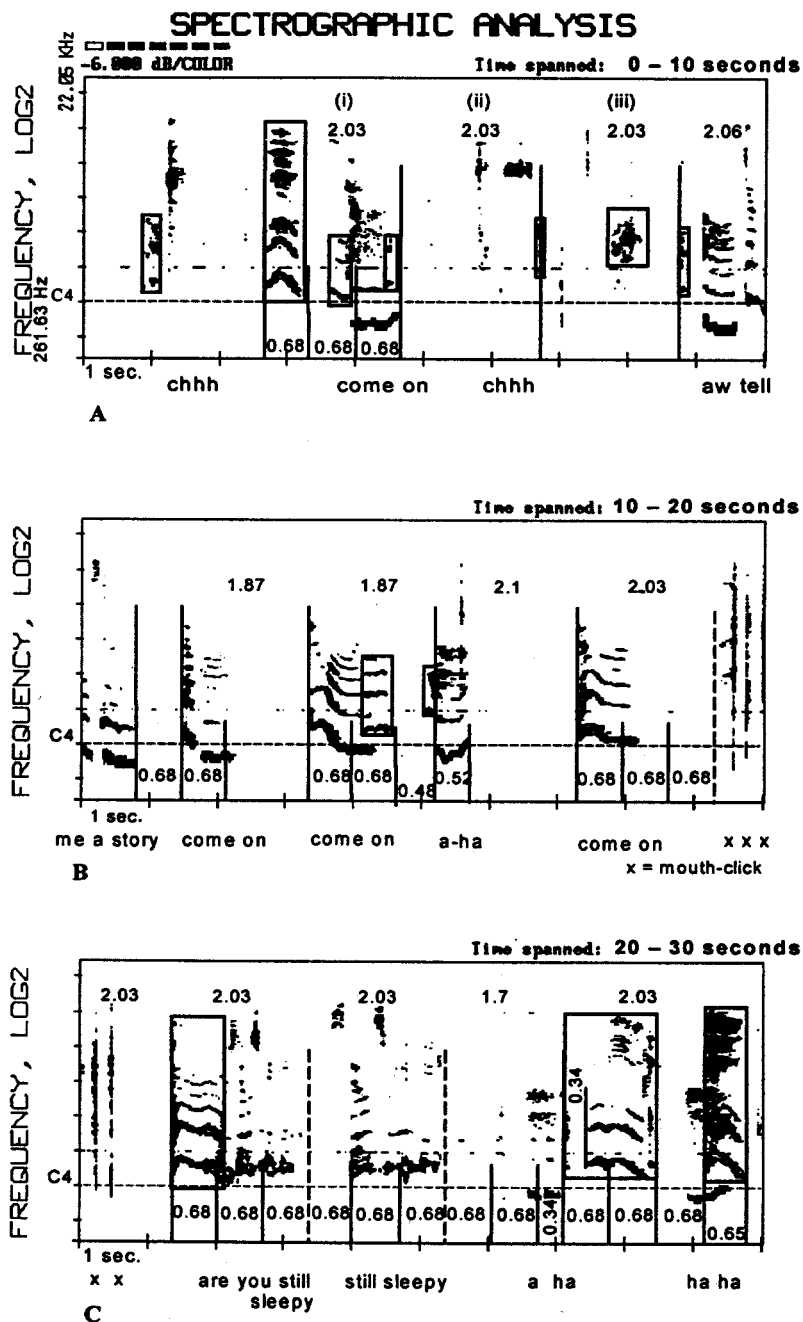


Figure 2. Sarah (12 weeks) vocalising with her mother.

In spectrograph A of Figure 2, we see the 0.68s interval emerge as the time unit by which the baby's and mother's utterances may be naturally divided. These first three 0.68s intervals form a larger interval of 2.03 seconds, which is surrounded by periods of silence⁵. This larger interval of 2.03 seconds is repeated twice more, and then repeated a third time in a "stretched" version of 2.06 seconds (which extends to spectrograph B). The first interval of 2.03 seconds (i) is defined by the beginning and end of a group of utterances from baby and mother; the end of the second interval (ii) is marked by the very next vocalisation by the infant; the third interval (iii) ends with the second of two vocalisations by the infant; the conclusion of the "stretched" interval is marked by the conclusion of a phrase by the mother. The continuation of intervals of 0.68s and 2.03s, as well as variations on these time units, is marked on spectrographs B and C of Figure 2 — the longer time units consisting of a single phrase by the mother (*e.g.*, "come on," "are you still sleepy"). As in Figure 1, a dashed-line bar-line indicates a division lying between vocal events.

In spectrograph C of Figure 2 we find an important time interval not yet discussed. At the point where the mother says "a ha," and immediately after this, two intervals of 0.34 seconds are indicated — the first interval is shown as belonging to the primary bar-structure, and the second is shown as having a subsidiary role. These two intervals of 0.34 seconds could have been shown as one interval of 0.68 seconds. However, for the interval of 0.68 seconds to lie at the natural boundaries of the baby's vocalisations of the last three seconds of spectrograph C, it is necessary to insert this smaller interval, which is exactly half the length of the dominant time interval. This suggests that a smaller time interval may be in operation "below" the interval of 0.68 seconds. In addition, this smaller interval, along with smaller intervals that are not simple fractions of the dominant interval, can be regarded as "correction intervals" — periods of time that allow mother and infant to shift the placement of the "beat", allowing one to meet the other in time, or "get in step". If the mother and infant are thought of as two persons meeting to walk together, these correction intervals allow their steps to coincide.

From Figures 1 and 2, it appears that the mother and infant tend to vocalise naturally in a co-ordinated and rhythmic fashion. Two different ways of "barring" the vocalisations have been presented. It is possible that the two different time structures — one using much longer intervals than the other, and the appearance of correction intervals — indicate "layers" of inter-dependent time structures.

Figures 1 and 2 show the vocalisations of infants of 6 and 12 weeks old respectively. Rhythmic elements are also found in vocal exchanges of premature infants with their parents. Figure 3, from a video documentary made by Saskia van Rees (1987) shows a spectrograph of a 2-month premature infant (32 weeks gestational age) vocalising with her father. In the figure, the infant's vocalisations are

(5) Although 3 times 0.68 is equal to 2.04, the units of 0.68 seconds are grouped into larger units of 2.03 seconds due to the rounding of the length of this larger unit to two decimal places.

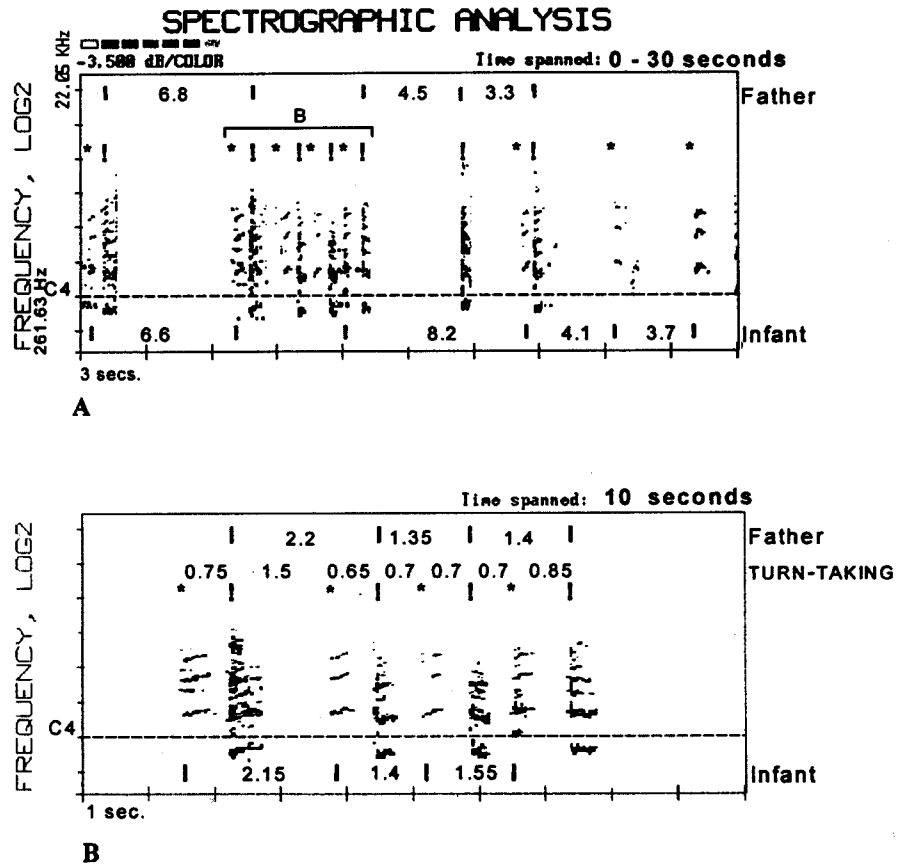


Figure 3. A two-month premature infant vocalising with her father.

marked by *, the father's by !. The father is kangarooing his baby — he is holding the baby inside his shirt. During this intimate physical contact, father and baby exchange “coos” in alternation. A hierarchy of time elements, described as “syllables”, “utterances” and “phrases”, has been reported in the spontaneous vocalisations of infants by Lynch (Lynch *et al.*, 1995). In spectrograph A of Figure 3, it can be seen that both father and baby are spacing intervals in what Lynch calls phrase units of about 4 seconds, and in spectrograph B, which is a detail of the region marked B on spectrograph A, we see that father and infant are imitating one another at syllable intervals of about 0.75 seconds — again, this time interval concurs with Lynch. Thus, even such an immature human has a complex periodicity of vocal expression comparable with that of adult expression, and is similar to the rhythmic patterns shown by infants in spontaneous vocalisations weeks and months after full-term birth.

4.2.

Quality is the second dimension of Communicative Musicality. Quality consists of the melodic and timbral contours of the vocalisations (equivalent to the contour and speed of the bodily gestures). Melodic contours are measured from pitch-plots, and timbre contours are measured from the combination of methods that will be introduced later in the paper. Let us look first at melodic contours.

While spectrographs are very good at allowing us to measure the time-intervals between vocalisations, they are not good at revealing high resolution fundamental frequency information, especially at lower frequencies. In order to investigate how the expressive movements of the mother's and baby's vocalisations move in frequency space during their interactions, a method is needed for graphing the pitch of the vocalisations.

Brown (1991) describes the calculation of a constant Q spectral transform that produces a constant pattern in the log frequency domain for sounds with harmonic frequency components. In Brown (1992), a method is described whereby this log frequency pattern is correlated with an ideal harmonic pattern, and thus the fundamental frequency can be determined. Brown's methods have been implemented by us in software, enabling the pitch of the vocalisations to be plotted.

Figure 4 shows a pitch plot of the data represented in Figure 1. A data point is calculated every 0.01 seconds, and the frequency resolution is one quarter of a tone. Pitch is represented on the vertical axis (in letter names — C4 is equivalent to middle-C) and time is represented along the horizontal axis. Numbers, which number the mother's and baby's vocalisations, are placed below the graph, and refer to the numbers in Figure 1. As in Figure 1, each of the baby's vocalisations is enclosed by a rectangle. Figure 4 also shows the strength of correlation between an "ideal" harmonic spectrum and the actual spectrum — roughly equivalent to how strongly pitched an event is. The key to this is shown on the right of the graph — the darker the small circle that indicates the pitch, the stronger the correlation. Like the spectrograph of Figure 1, these pitch-plots overlap one another by 1 or 2 seconds, as indicated.

Pitch plots allow us to observe how the pitches of the mother's and infant's vocalisations progress during the course of an interaction. The U-shaped pitch curves of the first three vocalisations in pitch-plot A are characteristic of a vocalisation that invites activity. Note how after the infant vocalises twice (numbers 5 and 6), with the second having a higher pitch than the first, the mother continues and exaggerates this upwards pitch movement with her very next vocalisation. In her vocalisation number (9), she summarises this pitch movement with an upwards sweep, which she follows with U-shaped pitch movement in this higher register (10). The infant then vocalises a short downwards moving pitch shape, which the mother immediately follows with an exaggerated downwards pitch movement. With the infant's flatter pitch shapes at (14) and (15), the mother replies with a flatter pitch shape. We see the mother being acutely aware of the pitch level and shape of the

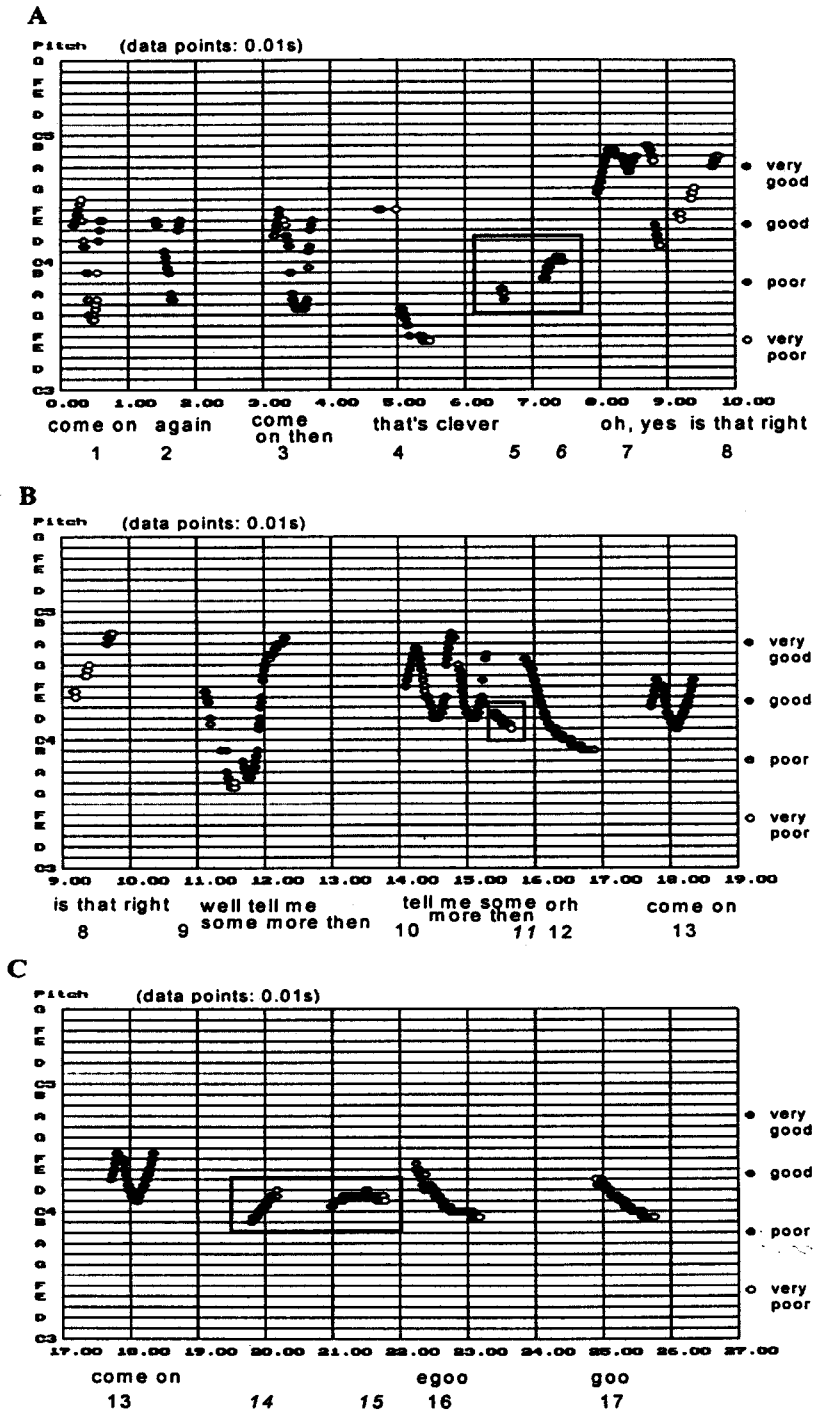


Figure 4. Pitch plot of Laura (6 weeks) and her mother, taken from data represented in Figure 1.

infant's vocalisations, and she acts to create a balance in their joint exploration of pitch space.

This last point — the creation of balance — is borne-out strongly in Figure 5. This figure shows the 26 seconds of vocalisations shown in Figure 4 condensed into a single pitch-plot. Here we see evidence of a ca. 20 second cycle. The mother's pitch rises at 8 seconds, and returns to middle-C at 26 seconds. In subsequent pitch-plots, this mother continues this 20 - 25 second cycle of pitch movement. Thus, it appears that mother and infant explore pitch-space in a methodical manner over both short and long intervals of time. The examination of pitch plots of other mothers over a span of 5 minutes, also reveals regular 20 - 25 second "waves" of pitch movement by the mother, with the infant following this trend in its own vocal pitches. We have also found evidence of very precise pitch and rhythmic matching by infants to their mother's vocalisations (both between and with maternal vocalisations). These infant vocalisations are often "musically logical" — particularly during songs sung by the mother (see section 4.3 below). Pitch, rhythmic and loudness movements by the mother and infant will have important emotional and motivational roles within their co-operative interaction.

The second element of Quality is that of timbre contour. Timbre is a multidimensional attribute of sound — unlike pitch and loudness, timbre cannot be adequately described by any one measure.

How can we measure timbre? One technique is the Tristimulus Method developed by Pollard and Janson (1982). The relative loudness of three spectral areas of a harmonic sound — the fundamental, harmonics 2-4, and harmonics 5-n — are compared. The results are plotted in a triangular space (which omits a time axis).

Figure 6 shows a tristimulus plot of the five vowel sounds sung to a fixed pitch. The horizontal axis measures the relative loudness of the middle harmonics (2-4), and the vertical axis measures the relative loudness of the upper harmonics (5-n). Thus, the placement of a sound within the tristimulus space gives an indication of its sound quality.

Figure 7 shows a tristimulus graph of the vocalisations represented in the spectrographs of Figure 1 and the pitch-plots of Figure 4. The numbers refer to the numbers found in these previous figures.

The infant's utterances are enclosed in a rounded rectangle. We can see that the timbre of the infant's vocalisations is very different from that of the mother — they lie in a different section of the tristimulus space. On the diagram, the mother's utterances have been loosely classified on the basis of their communicative function. We can see that on the basis of this grouping, utterances that share a similar function are found within a particular area of the tristimulus space⁶.

(6) The mother's utterance "Is that right?" (number 8), classified here as "inviting", might be seen instead as "affirming". However, its upwards pitch movement aligns it with other "inviting" utterances.

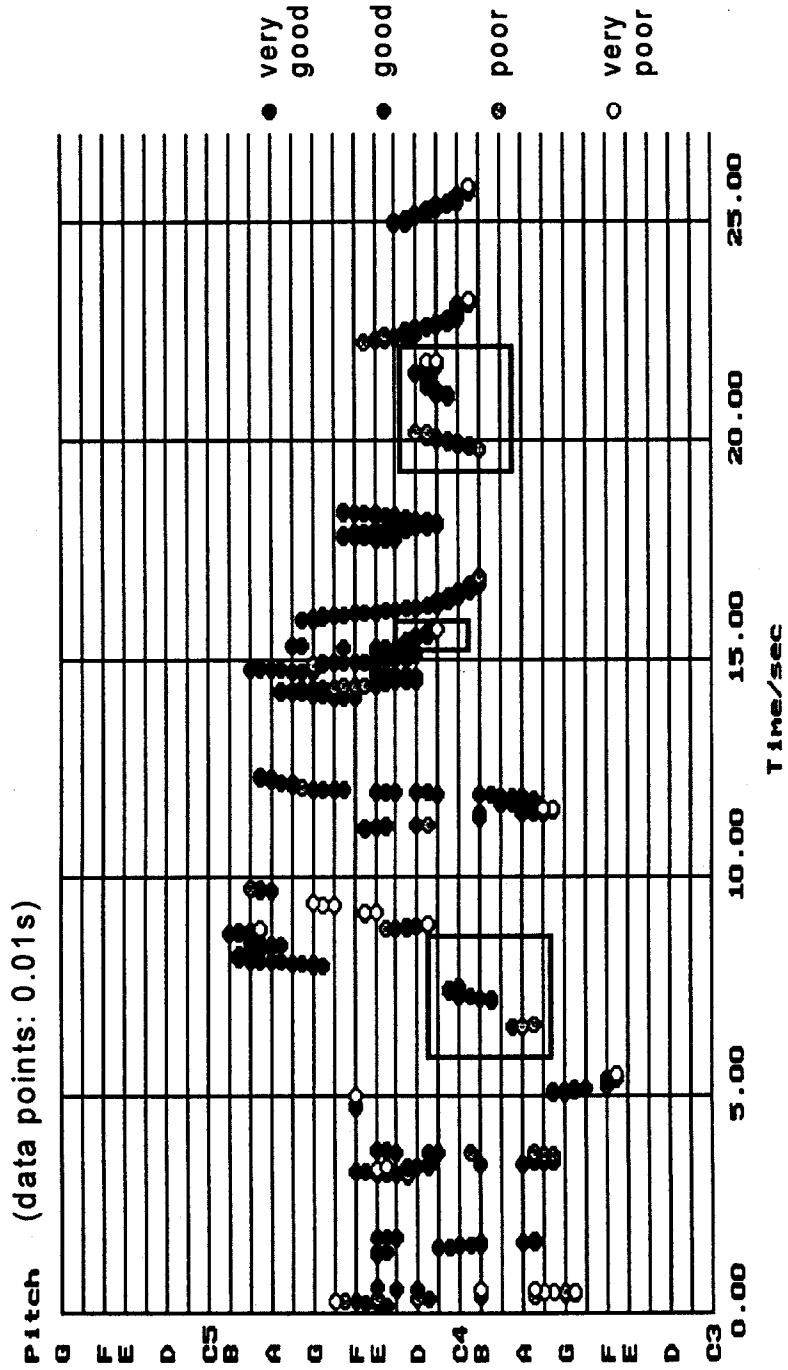


Figure 5. Pitch plot of Laura (6 weeks) — entire extract.

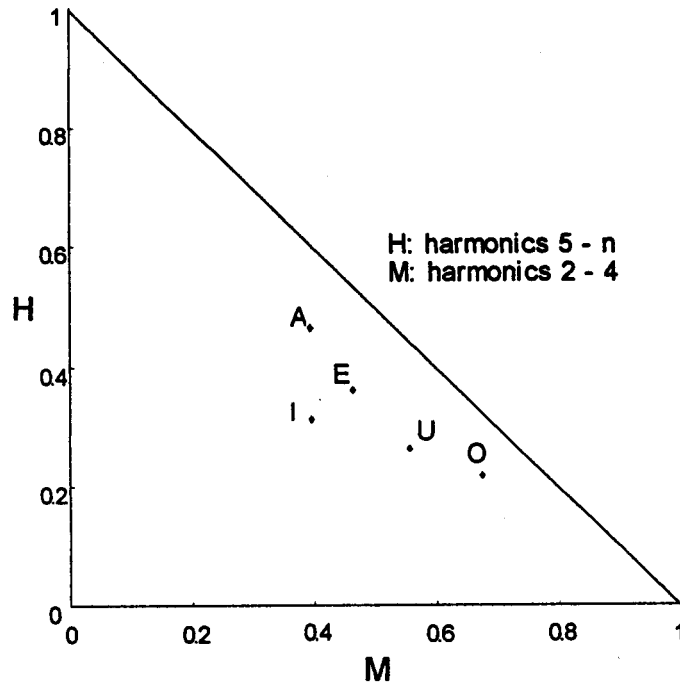


Figure 6. Tristimulus values of sung vowel sounds.

It was said that timbre is a multidimensional attribute — a number of different measures can be applied in order to gain a fuller understanding of the quality of the sound. Three other timbre measures that we have used are measures of sharpness, width and roughness. Sharpness, measured in acums, is calculated according to the formula proposed by Aures (1985). It is related to the position of the loudness centroid in a sound's spectrum. Timbral width is a measure of the fraction of loudness that lies outside of the loudest 1/3 octave band. It is a measure of how “expansive” or “narrow” a sound is heard to be. This measure is derived by Malloch (1997; and in press) from the Tristimulus Method. Roughness is caused by beating between partials. The model of roughness measurement we use is that proposed by Hutchinson and Knopoff (1978)⁷.

Figure 8 shows these three measures of timbre combined for the vocalisations of Laura (6 weeks) and her mother. Because these three measures have been combined

(7) The computer programs used to calculate these measures of timbre were all written at the University of Edinburgh for the author's PhD, and later adapted for this project.

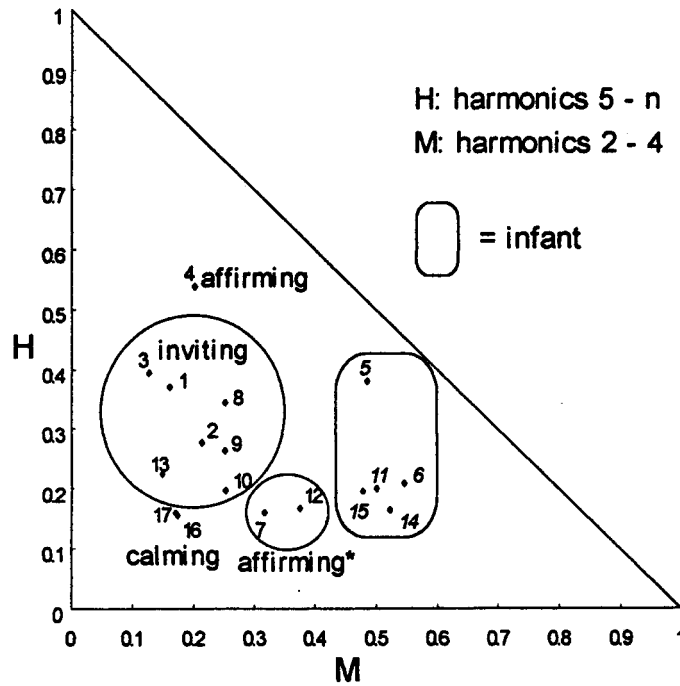


Figure 7. Tristimulus values for utterances shown in Figures 1 and 4 (Laura, 6 weeks).

on the one graph, the y axis is dimensionless. We are interested in the movement of the three measures relative to one another, within the context of the mother/infant vocalisations.

In Figure 8, each unbroken horizontal bar represents the average value of that quality (roughness, sharpness or width) for the duration of each vocalisation. To differentiate the different measures on the graph, the unbroken bars are “patterned”, and are joined by thin broken lines. As in previous graphs, a rectangle placed around the data shows that it is a representation of a vocalisation by the infant. The numbers below the vocalisations correspond to the numbering found in Figures 1, 4 and 7.

A particular trait of the mother that is shown by these graphs is the way in which her voice quality changes after each of the vocalisations by the infant. After all three sets of vocalisations by the infant, the timbral measures for the mother’s voice drop from the levels immediately prior to the infant’s vocalisation⁸. This may indicate

(8) The one exception is the mother’s vocalisation number 12. Here, there is a very slight rise in the measure for width. The other two measures, however, fall.

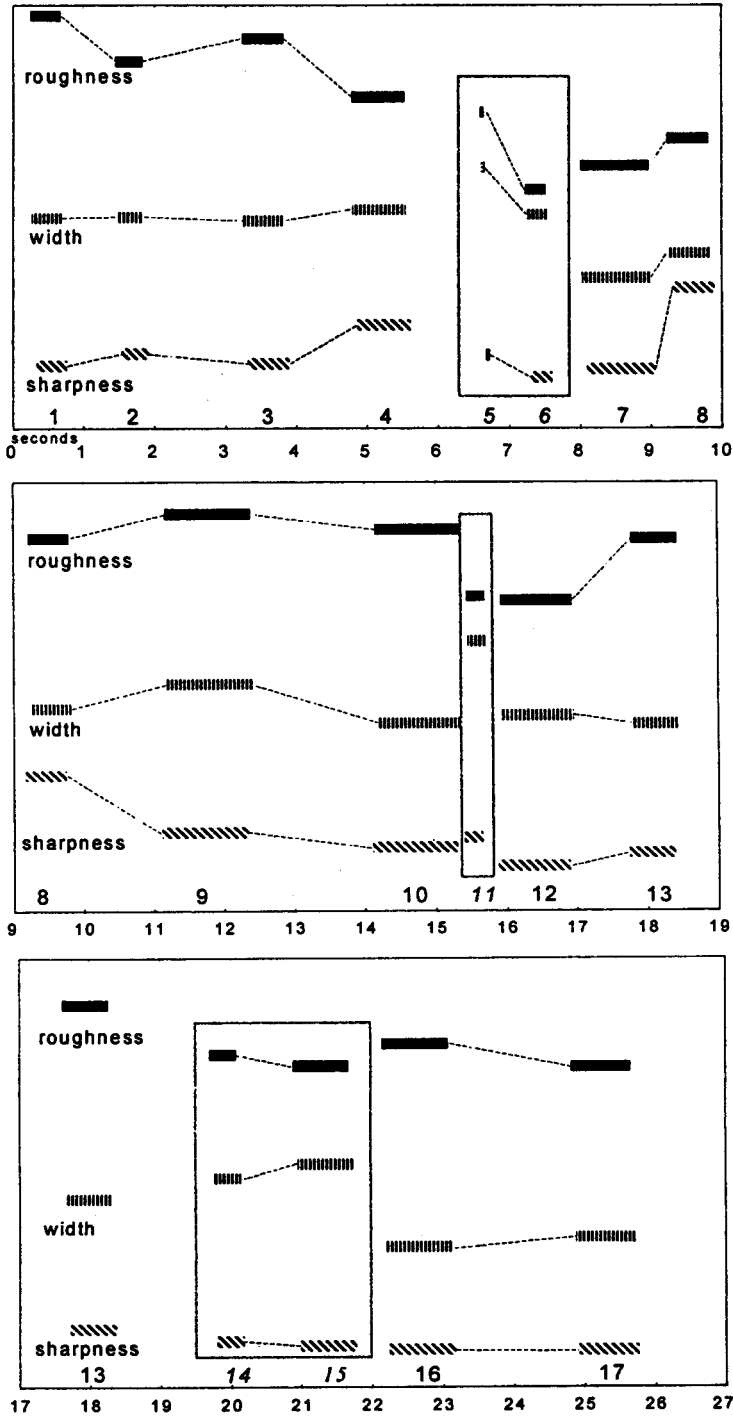


Figure 8. Measurements of Timbre for utterances shown in figures 1, 4 and 7.

that, by changing her voice quality, the mother signals to her infant that she has heard her. These measures may also indicate that the mother wishes to make her voice more similar to that of her infant. Referring back to Figure 7, we can see that the mother's vocalisations that occur after the infant's (numbers 7, 12 and 16) lie in the same horizontal region of the tristimulus space as all but one of the infant's vocalisations, indicating a timbral similarity.

We have discussed the elements of pulse and quality. All these attributes of the communicating mother/infant dyad combine to create the Narrative structure of their companionship.

4.3.

Narratives of individual experience and of companionship are built from the units of pulse and quality found in the jointly created gestures of vocalisations and bodily movement. Narratives are the very essence of human companionship and communication. Narratives allow two persons to share a sense of passing time, and to create and share the emotional envelopes that evolve through this shared time. They express innate motives for sharing emotion and experience with other persons and for creating meaning in joint activity with others (Stern, 1993; Trevarthen, 1988; Trevarthen, 1998).

Figure 9 represents a mother saying a nursery rhyme with her 4 month old baby girl⁹. Mother and infant are in a naturalistic surrounding, but the mother is not holding the baby so the infant is not being "bounced" in time with the rhyme. It is obvious, from the infant's reactions, that this is a rhyme the baby has heard many times before. The baby shows signs of pleasure, and smiles as soon as the mother begins. For the first verse, the baby does not vocally join in. In the second, the mother ceases to articulate the words - rather, she says a rhythm — "di dum, di dum, di dum". This rhythm is represented in musical notation in the figure. Below the mother's rhythm the vocalisations of the baby are also represented in musical notation, and the time of each bar is indicated in seconds above the bar. (For reasons of visual clarity, rests are omitted in the transcription where it does not create ambiguity.) In the second verse of the rhyme, we can see that the baby is joining in with the mother in a musical fashion. Her vocalisations are in time with the mother. Notice how the baby's contribution shows musical variety, as well as consistency. In the first bar of the second verse, the baby uses the "up-beat" idea that is so prominent in this rhyme. In the second and third bars, the baby vocalises on the beat. In the third bar, the baby appears to make use of the rest by introducing a new rhythmic idea in the form of a triplet (the baby laughs in a triplet rhythm). In the third verse, the baby consistently vocalises on the last beat of each bar, and provides the up-beat to the beginning of the verse, which the mother omits. This is very different to what the baby did during the second verse. It appears that the baby is changing her musical style from verse to verse.

(9) Recorded under the same circumstances and conditions as described in note 1.

The figure displays two musical stanzas, 'SECOND VERSE' and 'THIRD VERSE', each with a 'mother' and 'infant' part. The notation uses rhythmic patterns and rests to indicate participation. In the 'SECOND VERSE', the mother's part (2.2 s) and infant's part (2.2) are shown with various rhythmic values and rests. The 'THIRD VERSE' shows the mother laughing (2.5) and the infant's part (2.4) with similar rhythmic notation. The notation includes notes, rests, and dynamic markings like accents and slurs.

Figure 9. Musical notation representing the participation of mother and baby (4-month old) in a rhythm derived from the nursery rhyme Clap-a-clap-a-handies (rests are omitted where this does not cause ambiguity).

In the third bar of the third verse, the baby makes what can be described as a “musical joke”. After vocalising precisely on the last beat of bars 1 and 2 of verse 3, the baby still provides this beat in bar 3, but enters a semiquaver early. The baby vocalises particularly vigorously at this point — it may be that the baby wants to emphasise the fact that she is entering early. However, whether or not this is a deliberate act on the part of the infant, that this “early” vocalisation is sensed and appreciated by the mother is suggested by the mother’s laughter immediately following it. After this shared *tour-de-force* by both musical partners, the rhyme loses energy, and other play takes over.

From this example, we can see that an infant at 4 months of age is quite capable of entering into the “structure” of a musical game with an other, participating in a musically logical way. Her vocalisations during her mother’s rhyme show a true musical feeling — they support the musical structure of the rhyme — they never work against it.

In this last example, we have seen what can be described as a musical narrative created through the companionable interaction of a mother and her infant. We have also seen how timing is a vital element in mother/infant vocalisations, and how this timing can be represented as a series of bars, or as a series of smaller time-units. We have seen how mother and infant can use pitch imitation and complementation during their vocal exchanges — how both appear to have a strong sense of the pitch space that their joint vocalisations are covering, and how each relates to the other in a musical manner. We have seen how the mother is intuitively aware of the timbre of her voice, and how her modification of this timbre is an integral part of her vocal communication with her infant. Lastly, we have seen how a mother and her infant can jointly create a musical piece — both are musical partners within their communicative space.

In his article in this issue, Björn Merker (1999) suggests that synchronous chorusing and bodily gesture in our common ancestor with the chimpanzee, coming about as a result of sexual selection, may be the vital evolutionary step making the development of language possible. He suggests that the ability to vocalise and gesture together in time may underlie language. Similarly, it is our contention that the ability to act musically underlies and supports human companionship; that the elements of communicative musicality are necessary for joint human expressiveness to arise, and lie beneath, to a greater or lesser degree, all human communication.

At the start of this paper, we introduced the concept of communicative musicality, and we have emphasised the musicality of mother/infant vocalisations. However, as has been suggested above, this term is not to imply so much that mother/infant communication is musical — rather that what we generally call music is one particular drawing-together of the elements of pulse, quality, and narrative — elements that are intrinsic to all human communication. The elements of communicative musicality are the tools by which emotion is conveyed and thus companionship formed. What

happens when these elements are present to a lesser degree, or are absent? In her article in this issue (also see Robb, 1998), Louise Robb shows that in vocal exchanges between mothers suffering from post-natal depression and their babies, regularity of timing is present to a far lesser extent, and when it is, the regular units are slower than in happy mother/infant dyads. As well as this, the pitch of the mother's voice is generally lower, the pitch shapes that her vocalisations form are "flatter", and when the vocalisations do take-on a more "shapely" appearance, they are generally more drawn-out through time. Further research on the effect on the elements of communicative musicality due to post-natal depression is currently being undertaken by the author.

The movement from mother/infant vocalisations towards song is illustrated by Figure 10. This figure shows a pitch plot of a favourite nursery song *Rock-a-bye-baby*. As with the preceding pitch-plots, time is represented along the horizontal axis, and pitch along the vertical. Comparing the pitch shapes here to the pitch shapes we have seen in Figures 4 and 5, we can see a certain similarity — the pitch shapes in Figure 9 are more stylised, but we see the same operations of imitation and complementation in both instances. For example, the first three utterances by the mother in spectrograph A of Figure 4 show imitation. Utterance 4 introduces a new idea. The baby introduces yet another idea — a rising figure — which the mother completes with utterance 7, and then elaborates with utterance 8. Utterances 9 to 17 show at first a big sweep of pitch upwards, and then a gradual coming to rest.

We can see very similar processes at work in the poetic and musically "dramatic" lullaby. The first two phrases of Figure 10 (0 - 14 seconds) show imitation, along with some variation. The last phrase (22 seconds to the end) shows a new idea, which is completed by the downward movement to the end of the piece. The way in which the lullaby has a shape which leads to a climax at 22 seconds and then resolution at its end, is very similar to the overall shape of the vocalisations as shown in Figure 5 — a climax at around 7 seconds, and then a movement towards a resolution.

5

CONCLUSION

Communicative musicality is the art of human companionable communication. It consists of our innate abilities, which function from birth, for being able to move sympathetically with an other. It is the vehicle which carries emotion from one to the other. When our ability to share emotions is impaired, it appears that the elements of communicative musicality change in ways that make them less "musical".

We have discussed communicative musicality in terms of pulse, quality and narrative. We have seen that in these three areas systematic movement occurs between mother and infant — movement that allows mother and infant to express themselves in ways that are sympathetic with the other.

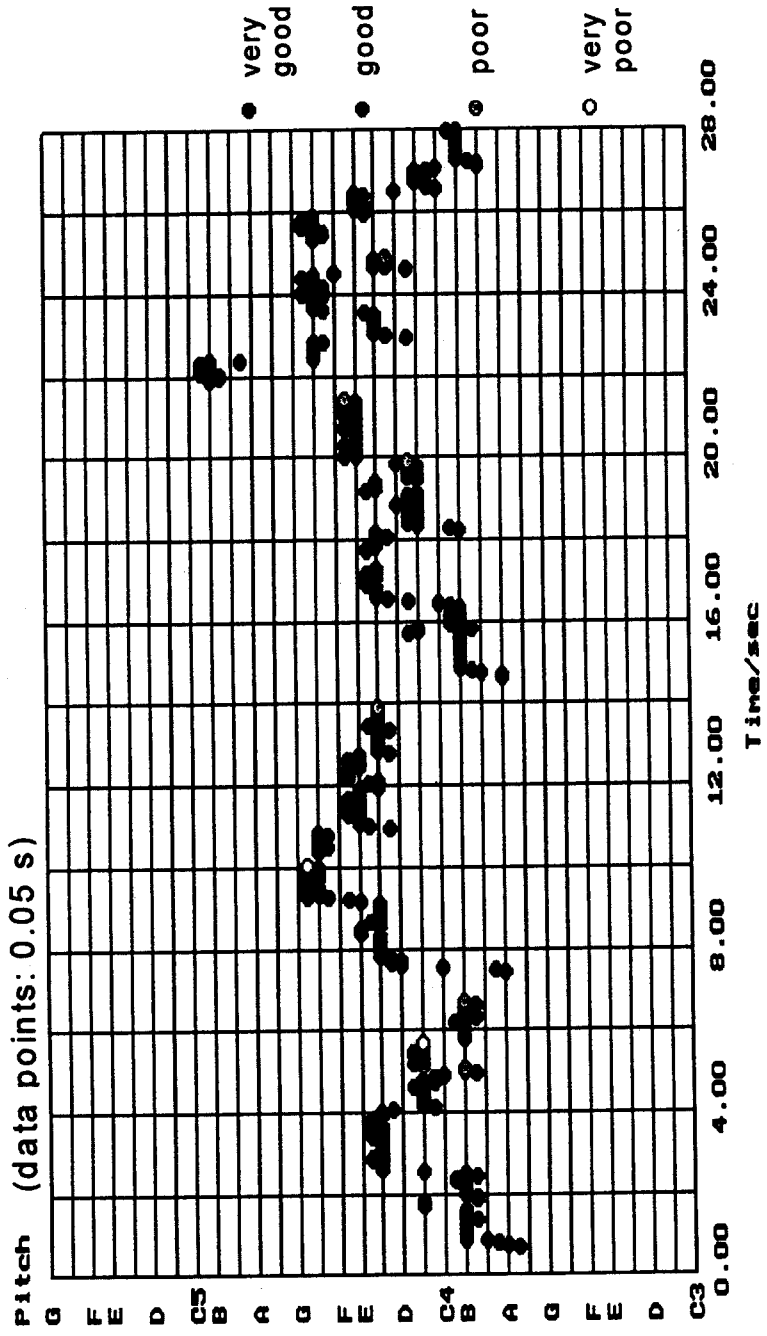


Figure 10. Pitch plot of Rock-a-bye-baby.
The words are: Rock-a-bye baby on the tree top / When the wind blows the cradle will rock / When the bough breaks the cradle will fall / Down will come baby cradle and all.

Movement — gestural, vocal and emotional — is what allows communicative musicality to occur. When this movement is constrained or impeded, communicative musicality suffers, and companionship suffers. Acoustic analysis of vocalisations allows us to see into this movement in a very precise and illuminating way¹⁰.

(10) I wish to dedicate this paper to Prof. Colwyn Trevarthen, without whose passion and drive for understanding I would never have been inspired to enter the fascinating world of infant communication.

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• REFERENCES

- Aures, W. (1985). Berechnungsverfahren für den sensorischen Wohlklang beliebiger Schallsignale. *Acustica*, 59, 130-41.
- Beebe, B., Jaffe, J., Feldstein, S., Mays, K., & Alson, D. (1985). Inter-personal timing: The application of an adult dialogue model to mother-infant vocal and kinesic interactions. In F. M. Field and N. Fox (eds.), *Social Perception in Infants*. Norwood, NJ: Ablex.
- Beebe, B., & Lachmann, F. M. (1994). Representation and internalisation in infancy: three principles of salience. *Psychoanalytic Psychology*, 11(2), 127-65.
- Beebe, B., Stern, D., & Jaffe, J. (1979). The kinesic rhythm of mother-infant interactions. In A. W. Siegman and S. Feldstein (eds.), *Of Speech and Time: Temporal Speech Patterns in Interpersonal Contexts*. Hillsdale, NJ: Erlbaum.
- Bettes, B. (1988). Maternal depression and motherese: temporal and intonational features. *Child Development*, 59, 1089-96.
- Brown, J. C. (1991). Calculation of a constant Q spectral transform. *Journal of the Acoustical Society of America*, 89, 425-34.
- Brown, J. C. (1992). Musical fundamental frequency tracking using pattern recognition method. *Journal of the Acoustical Society of America*, 92, 1394-1402.
- Burford, B. (1992). Communicating through movement and posture. In W. MacGillivray, W. I. Fraser and A. Green (eds.), *Hallas' Caring for People with Mental Handicap* (pp. 94-102). London: Butterworth-Heinemann Ltd.
- Burford, B., & Trevarthen, C. (1997). Evoking communication in Rett syndrome: Comparisons with conversations and games in mother-infant interaction. *European Child and Adolescent Psychiatry*, 6, 1-5.
- Condon, W. S., & Sander, L. W. (1974). Neonate movement is synchronized with adult speech: interactional participation and language acquisition. *Science*, 183, 99-101.
- De Casper, A. J., & Fifer W. P. (1980). Of human bonding: newborns prefer their mother's voices. *Science*, 208, 1174-76.
- Fernald, A. (1992). Meaningful melodies in mothers' speech to infants. In H. Papoušek, U. Jurgens, and M. Papoušek (eds.), *Nonverbal Vocal Communication: Comparative and Developmental Aspects* (pp. 262-82). Cambridge: Cambridge University Press/Paris: Editions de la Maison des Sciences de l'Homme.
- Fifer, W. P., & Moon, C. M. (1995). The effects of fetal experience with sound. In J.-P. Lecanuet, W. P. Fifer, N. A. Krasnegor and W. P. Smotherman (eds.), *Fetal Development: A Psychobiological Perspective* (pp. 351-66). Hillsdale, NJ: Erlbaum.
- Fogel, A., & Hannan, T. E. (1985). Manual actions of nine- to fifteen-week-old human infants during face-to-face interaction with their mothers. *Child Development*, 56, 1271-79.
- Fogel, A., & Thelen, E. (1987). Development of early expressive action from a dynamic systems approach. *Developmental Psychology*, 23, 747-61.
- Fraiberg, S. (1979). Blind infants and their mothers: an examination of the sign system. In M. Bullowa (ed.), *Before Speech: The Beginning of Interpersonal Communication* (pp. 149-69). London: Cambridge University Press.
- Greiser, D. L., & Kuhl, P. K. (1988). Maternal speech to infants in a tonal language: support for universal prosodic features in motherese. *Developmental Psychology*, 24, 14-20.
- Hauge, T. S., & Hallan Tønsberg, G. E. (1996). The musical nature of prelinguistic interaction. *Nordic Journal of Music Therapy*, 5(2), 63-75.

- Heimann, M. (1989). Neonatal imitation, gaze aversion and mother-infant interaction. *Infant Behaviour and Development*, 12, 495-505.
- Hepper, P. G. (1995). The behaviour of the fetus as an indicator of neural functioning. In J.-P. Lecanuet, W. P. Fifer, N. A. Krasnegor and W. P. Smotherman (eds.), *Fetal Development: A Psychobiological Perspective* (pp. 405-17). Hillsdale NJ: Erlbaum.,
- Hutchinson, W., & Knopoff, L. (1978). The acoustic component of Western consonance. *Interface*, 7(1).
- Jaffe, J., Stern D. N., & Peery J. C. (1973). Conversational coupling of gaze behaviour in prelinguistic human development. *Journal of Psycholinguistic Research*, 2, 321-30.
- Lynch, M. P., Oller, D. K., Steffens, M. L., & Buder, E. H. (1995). Phrasing in prelinguistic vocalisations. *Developmental Psychobiology*, 28, 3-25.
- Malloch, S. (1997). *Timbre and Technology: an analytical partnership*. Ph.D. thesis, Faculty of Music, University of Edinburgh.
- Malloch, S. (in press). Timbre and Technology: An Analytical Partnership. *Contemporary Music Review*.
- Meltzoff, A. N., & Moore, M. K. (1977). Imitation of facial and manual gestures. *Science*, 198, 75-80.
- Merker, B. (1999). Synchronous chorusing and the origins of music. (This volume).
- Murray, L., & Stein, A. (1989). The effects of post-natal depression on the infant. *Baillieres Clinical Obstetrics and Gynaecology*, 3(4), 921-33.
- Murray, L., & Trevarthen C. (1985). Emotional regulation of interactions between two-month-olds and their mothers. In T. Field and N. Fox (eds.), *Social Perception in Infants*. Norwood, N.J.: Ablex.
- Murray, L., Fiori-Cowley, A., Hooper, & Cooper, P. (1996). The impact of postnatal depression and associated adversity on early mother-infant interactions and later outcome. *Child Development*, 67, 2512-26.
- Nadel, J., & Butterworth, G. (eds.) (1999). *Imitation in Infancy*. Cambridge: Cambridge University Press.
- Nadel, J., Carchon, I., Kervella, C., Marcelli, D., & Réserbat-Plantey, D. (1999). Expectancies for social contingency in 2-month-olds. *Developmental Science*, 2(2), 164-73.
- Papoušek, H., & Bornstein, M. H. (1992). Didactic interactions: intuitive parental support of vocal and verbal development in human infants. In H. Papoušek, U. Jurgens and M. Papoušek (eds.), *Nonverbal Vocal Communication: Comparative and Developmental Aspects*. Cambridge: Cambridge University Press/Paris: Editions de la Maison des Sciences de l'Homme, 209-29.
- Papoušek, H., & Papoušek, M. (1987). Intuitive parenting: A dialectic counterpart to the infant's integrative performance. In Osofsky (ed.), *Handbook of Infant Development* (2nd edition). New York: Wiley.
- Papoušek, H., & Papoušek, M. (1997). Fragile aspects of early social interaction. In L. Murray and P. J. Cooper (eds.), *Postpartum depression and child development* (pp. 35-53). New York: Guilford Press.
- Papoušek, M. (1992). Early ontogeny of vocal communication in parent-infant interactions. In H. Papoušek, U. Jurgens and M. Papoušek (eds.), *Nonverbal Vocal Communication: Comparative and Developmental Aspects* (pp. 230-61). Cambridge: Cambridge University Press/Paris: Editions de la Maison des Sciences de l'Homme.
- Pollard, H., & Janson, E. V. (1982). A tristimulus method for the specification of musical timbre. *Acustica*, 51, 162-71.

- Preisler, G., & Palmer, C. (1986). The function of vocalization in early parent-blind child interaction. In B. Lindblom and R. Zetterstrom (eds.), *Precursors of Early Speech. Basingstoke* (pp. 269-77). New York: Macmillan.
- Robb, L. (1998). *Emotional-musicality in mother-infant vocal affect: a study of post-natal depression*. Fourth year honours dissertation, Department of Psychology, University of Edinburgh.
- Stern, D. (1993). The role of feelings for an interpersonal self. In U. Neisser (ed.), *The Perceived Self* (pp. 205-15). Cambridge: Cambridge University Press.
- Stern, D. N. (1985). *The Interpersonal World of the Infant: A View from Psychoanalysis and Development Psychology*. New York: Basic Books
- Stern, D. N., Hofer, L., Haft, W., & Dore, J. (1985). Affect attunement: The sharing of feeling states between mother and infant by means of intermodal fluency. In T. N. Field and N. Fox (eds.), *Social perception in infants*. Norwood, NJ: Ablex.
- Stern, D. N., Speiker, R. K., & Mackain, K. (1982). Intonation contours as signals in maternal speech to prelinguistic infants. *Developmental Psychology*, 18(5), 727-35.
- Trehub, S. E., & Trainor, L. J. (1993). Listening strategies in infancy: the roots of music and language development. In S. McAdams and E. Bigand (eds.), *Thinking in sound*. Oxford: Oxford University Press.
- Trehub, S. E., Trainor, L. J., & Unyk, A. M. (1993). Music and speech processing in the first year of life. *Advances in Child Development and Behaviour*, 24, 1-35.
- Trevarthen, C. (1980). The foundations of intersubjectivity: development of interpersonal and cooperative understanding in infants. In D. Olson (ed.), *The social foundation of language and thought*. New York: Norton.
- Trevarthen, C. (1986). Form, significance and psychological potential of hand gestures of infants. In J.-L. Nespoulous, P. Perron and A. R. Lecours (eds.), *The biological foundation of gestures: Motor and semiotic aspects* (pp.149-202). Hillsdale, NJ: Erlbaum.
- Trevarthen, C. (1988). Sharing makes sense: Intersubjectivity and the making of an infant's meaning. In R. Steele and T. Threadgold (eds.), *Language Topics: Essays in Honour of Michael Halliday* (pp. 177-99). Amsterdam and Philadelphia: John Benjamins.
- Trevarthen, C. (1998). The concept and foundations of infant intersubjectivity. In S. Bråten (ed.), *Intersubjective Communication and Emotion in Early Ontogeny* (pp. 15-46). Cambridge: Cambridge University Press.
- Trevarthen, C., & Burford, B. (1995). The central role of parents: how they can give power to a motor impaired child's acting, experiencing and sharing. *European Journal of Special Needs Education*, 10(2),138-48.
- Trevarthen, C., Murray, L., & Hubble, P. (1981). Psychology of infants. In J. Davis and J. Dobbing (eds.), *Scientific foundations of clinical paediatrics* (2nd edition). London: W. Heinemann Medical Books Ltd.
- Tronick, E. Z., & Weinberg, M. K. (1997). Depressed mothers and infants: Failure to form dyadic states of consciousness. In L. Murray and P. J. Cooper (eds.), *Postpartum Depression and Child Development* (pp.54-81). New York: Guilford Press.
- Tronick, E. Z., Als, H., & Brazelton, T. B. (1980). Monadic phases: A structural descriptive analysis of infant-mother face-to-face interaction. *Merrill-Palmer Quarterly of Behaviour and Development*, 26, 1-24.
- van Rees, S., & de Leeuw, R. (1987). *Born Too Early: The Kangaroo Method with Premature Babies*. Video by Stichting Lichaamstaal, Scheyvenhofweg 12, 6093 PR, Heythuysen, The Netherlands.

Weinberg, M. K., & Tronick, E. Z. (1994). Beyond the face: An empirical study of infant affective configurations of facial, vocal, gestural and regulatory behaviors. *Child Development*, 65, 1503-15.

• Madres e hijos y la musicalidad comunicativa

Utilizando la música como modelo, examinamos las vocalizaciones madres/hijos utilizando análisis acústicos basados en procedimientos informáticos. Primeramente, resumimos la investigación anterior, que demuestra la importancia de ambas partes en la comunicación madre/hijo. Nuestros métodos son utilizados para analizar entonces pulso, calidad y narrativa en las vocalizaciones madres/hijos. Estos tres elementos comprenden la "musicalidad comunicativa": aquellos atributos de la comunicación humana que son particularmente explotados por la música que permite surgir la compañía coordinada. El pulso es estudiado mediante análisis espectrográficos, descubriéndose que los intervalos regulares de tiempo sirven para coordinar el conjunto de vocalizaciones de madres e hijos. La calidad consiste en el estudio del espectro de alturas de las vocalizaciones y su timbre. El estudio de la altura es posible gracias a un software desarrollado por nosotros, que utiliza una constante Q de transformación espectral. Examinamos cómo los niños y las madres estructuran su exploración total del espacio de alturas a pequeña y a gran escala. El timbre se describe mediante una variedad de medidas acústicas — agudeza, nitidez, dureza y amplitud. Constatamos los cambios de calidad de la voz de la madre en respuesta a los del niño. La narrativa combina pulso y calidad, lo que permite a dos personas compartir un sentido del paso del tiempo. Esto se ilustra mediante el examen de la compañía musical que se crea entre una madre y su bebé cuando ella canta una canción de cuna. Concluimos que la musicalidad comunicativa es vital para la comunicación padres/hijos.

• Madri e bambini e la musicalità comunicativa

Usando la musica come modello, esaminiamo la vocalizzazione madre/bambino utilizzando analisi acustiche computerizzate. Innanzitutto riassumiamo le ricerche passate, che dimostrano l'importanza di entrambe le parti nella diade madre-bambino. Introduciamo quindi i nostri metodi per analizzare pulsazione, qualità e narratività nelle vocalizzazioni madre-bambino. Questi tre elementi costituiscono la "musicalità comunicativa": gli attributi cioè della comunicazione umana, particolarmente sfruttati in musica, che fanno nascere una sintonia coordinata. La pulsazione viene analizzata utilizzando analisi spettrografiche, e vengono scoperti intervalli temporali regolari che servono a coordinare le vocalizzazioni di madre e bambino. La qualità consiste sia nell'altezza delle vocalizzazioni, che nel loro timbro. Diagrammi dell'altezza dei suoni vengono ottenuti con un software da noi sviluppato, che utilizza una costante trasformazione spettrale (Q-spectral trasform). Esaminiamo come il bambino e sua madre strutturano la loro esplorazione congiunta dello spazio sonoro su piccola e grande scala. Il timbro viene descritto con una varietà di misure acustiche — valori di acurezza, intensità, durezza e altezza. Abbiamo riscontrato che la voce della madre modifica la propria qualità in funzione di quella del bambino. L'elemento narrativo combina insieme

pulsazione e qualità : esso permette a due persone di condividere la sensazione del trascorrere del tempo. Ciò viene illustrato dall'esame della sintonia musicale che si crea tra una madre ed il suo bambino quando lei gli canta una filastrocca. Concludiamo che la musicalità comunicativa è vitale per un'armoniosa comunicazione genitori/bambino.

- **Mère et nourrisson : la musicalité de communication**

Prenant appui sur la musique, nous analysons par ordinateur les éléments acoustiques des vocalisations entre mère et nourrisson. Après un rappel des travaux qui ont éclairé le rôle de chacun des partenaires dans la dyade mère-nourrisson, nous présentons les méthodes sur lesquelles nous fondons l'analyse de la pulsation rythmique, de la qualité et de la narration des vocalisations entre la mère et son bébé. Ces trois éléments constituent ce que nous qualifions de "musicalité de communication" : les attributs de la communication humaine, singulièrement exploités en musique, qui autorisent l'émergence d'une camaraderie coordonnée. L'analyse spectrographique de la pulsation rythmique révèle la présence d'intervalles temporels réguliers autorisant la coordination des vocalisations communes de la mère et du nourrisson. La qualité se rapporte au contour de hauteur des vocalisations et à leur timbre. Le tracé des hauteurs est dérivé par un logiciel développé par transformation spectrale de la constante Q. Nous étudions comment le nourrisson et sa mère structurent, aux échelles macro et microscopiques, leur exploration mutuelle de l'espace des hauteurs. Le timbre est décrit par diverses mesures acoustiques qui constituent les trois valeurs du stimulus : hauteur, approximation et ampleur. Il est à noter que la mère modifie la qualité de sa voix en réponse à celle de l'enfant. La narration associe pulsation rythmique et qualité; elle permet à deux individus de partager le sens de l'écoulement du temps, comme le montre l'étude de la camaraderie musicale qui s'instaure entre une mère et son bébé lorsqu'elle lui chante des comptines. Nous en déduisons que la musicalité est vitale à l'attrait de la communication entre l'un des parents et le nourrisson.

- **Mütter und Kleinkinder und die kommunikative Musikalität**

Mit Musik als unserem Modell untersuchen wir auf der Basis computerunterstützter akustischer Analyse Mutter/Kleinkind-Vokalisationen. Wir geben zunächst eine Zusammenfassung der bisherigen Forschung, welche die Wichtigkeit beider Teile in der Mutter/Kind-Dyade zeigt. Unsere Methoden werden dann für die Analyse von Puls, Qualität und Narration der Mutter/Kind-Dyade eingesetzt. Diese drei Elemente bilden die „kommunikative Musikalität“, nämlich jene Attribute der menschlichen Kommunikation, welche besonders in der Musik ausgenützt werden

und die eine koordinierte Partnerschaft aufzubauen erlauben. Puls wird mittels spektrographischer Analyse untersucht, und es werden regelmäßige Zeitintervalle entdeckt, welche der Koordination der Stimmäußerungen von Mutter und Kind dienen. Qualität besteht sowohl aus der Tonhöhenkontur der Stimmäußerungen als auch aus deren Klangfarbe. Tonhöhenplots werden mittels einer von uns entwickelten Software abgeleitet, welche eine konstante Q-Spektraltransformation verwendet. Wir untersuchen, wie das Kleinkind und die Mutter ihre gemeinsame Erkundung des Tonraumes im kleinen und großen strukturieren. Klangfarbe wird beschrieben durch eine Mehrzahl akustischer Meßdaten: Tristimuluswerte, Schärfe, Rauigkeit und Weite. Wir finden, daß die Stimme der Mutter in Reaktion auf jene des Kindes ihre Qualität ändert. Narration verbindet Puls und Qualität: sie ermöglicht zwei Personen einen gemeinsamen Sinn für den Zeitablauf. Dies wird durch die Untersuchung der musikalischen Partnerschaft illustriert, welche zwischen einer Mutter und ihrem Baby beim Singen eines Kinderreims erzeugt wird. Wir kommen zu dem Schluß, daß die kreative Musikalität für eine harmonische Eltern/Kleinkind-Kommunikation grundlegend ist.