INTRINSIC MUSICALITY: RHYTHM AND PROSODY IN INFANT-DIRECTED VOICES

Niki Powers
University of Edinburgh

Abstract

The theory of musical acoustics and new computerised acoustic analysis were applied to obtain a precise and comprehensive account of parents' vocal communication and it's motivating and regulatory potential in the first year of life. Infants' sensitivity for the rhythms and melodic or prosodic features of adult vocalisations, i. e. their adaptations for 'Communicative Musicality' (Malloch, 1999) was studied, with particular attention to responses to infant-directed forms of maternal vocalisations (speech, song and sound games) in which rhythmic expression and affective quality are enhanced.

Seven mother-infant dyads were filmed in their own homes, every two weeks for three months. Mothers were instructed to play with their infants as they normally do. The pairs were filmed, and DAT recordings were made of each session. Video microanalysis using a well-established category system (Trevarthen and Marwick, 1982) was carried out on segments of video, to elucidate the nature of the infants' non-vocal communicative behaviours and how these developed over time. Inter-rater reliability was established at 87.8%. Acoustic analysis was carried out on corresponding segments of DAT tape, using Hypersignal computer software to produce spectrographic and fundamental frequency pitch information (Malloch et al., 1997). This gave a comprehensive description of the vocal behaviours of both mothers and infants and the overall temporal coordination of their interactions. It also allowed a preliminary examination of how mother and infant vowel sounds are placed in the overall structure of the interaction. Mother and infant vowel sounds were further analysed using Praat Linguistic software. Small segments of vowel sounds were copied into the Praat software program and subjected to a formant analysis. Structural differences were noted.

The descriptions that were gained using this method showed that mothers and infants both actively participate in adapting and regulating their communicative interactions.

Preliminary vowel analysis showed that vowels play a key role in temporal ordering and expression and perception of emotional affect of both partners.

Key Words: musical acoustics, communicative musicality, rhythmic expression, emotional affect

INTRODUCTION

Research with infants has over the last two decades provided a fascinating insight into the foundations of communication. However, many questions still remain and there

Author's email: Niki.Powers@ed.ac.uk

is speculation and controversy over the precise nature of features underlying what we understand so far about these foundations.

The problem is undoubtedly a complex one, but has relevance for researchers in many fields within psychology. What we are communicating contains several features alongside our semantic message. One important feature of all communication is the emotional affect, and research into infant communication has led to interesting conclusions about the systems within the human brain that allow us to communicate, first our emotional, and second our semantic messages. If research can establish how infants produce communicative behaviour from birth, how they can perceive communicative behaviour directed to them from others, and what communicative features they pay attention to, this will advance our understanding of the higher cognitive processes of language comprehension.

More recent research with infants has uncovered evidence to support that neonate communicative systems are functioning in an organised way. It is accepted that there is some kind of temporal 'sense' to what infants perceive and react too. Wittman and Poppel (1999) present evidence for two fundamental levels of temporal processing in the Central Nervous System. A high frequency level operating around a 30ms time interval provides information about temporal order and control. A low frequency level, operating around a 3s interval, combines smaller, high frequency components into comprehensible units. However, underlying features of this temporal processing are elusive, mainly because they are so complex in their nature. Wittman and Poppel (1999) propose that high frequency temporal processing is evident in action and perception tasks, and suggest that this may be evidence for a 'neuronal clock', possibly situated in the left cerebral cortex and operating throughout communicative, perceptual and motor domains whenever precise central control is exercised in action and experience.

Infants, even in the early weeks, have the capacity to attend to the parental language over others and they can distinguish languages of the same type as their own from those of a different type; for example, differentiating stress-timed and syllable timed languages. So they are preparing to hear and produce speech. They are not just reacting to random events or practising making sounds. Nevertheless, the full extent of infants' adaptations for hearing and acquisition of language is not known. It is still not clear what the specific underlying features are, that attract infants' interest, and prosodic regularities are extremely difficult to pin down.

By exploring different levels of phonetic and intonational expression in infant-directed speech, linguists have recently make significant advances in understanding the 'intuitive parenting' of speech to infants (Stern et al., 1982). Understanding the way that communicative information is processed gives only part of the picture. Communicating humans are not only selectively processing information, they move voluntarily and often reacting with irrational intuition. Human motivation and levels of ability and interest seem to have an important effect on the development of underlying communicative features.

There is a growing realisation, mainly as a consequence of descriptive analysis of parents' vocalisations and of infants' attention to their imitations, and practice to themselves when alone (self-imitations), that the foundation is built on intuitive motives of

infants, which parents match and support, and particularly on shared rhythms of expressive action, and emotional qualities in vocal, facial and gestural expression (Hubley and Trevarthen, 1979; Trevarthen, 1999, 2000). Malloch et al's Communicative Musicality (1997) is an integrated theory to explain these 'motive co ordinations' in infants and parents. It uses musicological descriptions of mother infant vocal interactions to precisely characterise the inherent foundations of human consciousness, action and thinking that enable an infant and an adult to coordinate in a coherent flow of expression.

Communicative Musicality

The Communicative Musicality Model (Malloch et al., 1997, Malloch, 1999; Trevarthen, 1999, 2000) offers the potential to examine underlying features of vocal communication between mothers and their infants. This method generates a visual description of acoustic parameters. Specific features such as pitch, loudness, quality and timbre are shown graphically as a function of time, and temporal patterns can be measured. Using this method, researchers are beginning to answer some of the questions about underlying features of communicative behaviour. Malloch et al (1997) found that the musical qualities of 'pulse', 'quality' and 'narrative' were utilised by a mother and her 6-week-old infant throughout their communicative interactions, to coordinate and regulate emotional affect. Further examination confirmed that communicative interactions between mothers and their infants are highly organised and closely coordinated.

Co-ordinated communicative interactions are evident in infants from birth (Trevarthen, 2000). Newborn infants show an intuitive preference for and are regulated by, the maternal voice (De Casper and Fifer, 1980; Fifer and Moon, 1995; Spence and Freeman, 1996). Early acoustic encounters have been shown to have an effect on infant perception that is especially relevant when they are being exposed to language (Kuhl, 1998). What is still unknown, are the specific features of the maternal voice that attract the infant's attention and how these characteristics are utilised by both mother and infant to co-ordinate their affective expression. Although many details are being discovered, the processes involved are complex and a lot of research is still needed.

Stern et al (1982) demonstrated that American English-speaking mothers employ particular intonation contours in specific interactional contexts, when communicating with their 2-month-old infants. Mothers used rising intonation contours to encourage interpersonal contact with their infants and sinusoidal and bell-shaped intonation contours to maintain a positive emotional state in the infant. It appears that maternal intonation contours are marking suprasegmental features for the infant and they are teaching the infant context-specific patterns of communication.

It is well established that pitch range is greatly expanded in maternal speech (Stern et al., 1982). Salient features are exaggerated by the parent, which makes them perceptually attractive to the infant. Some features of maternal intonation contours appear to be critical in the regulation of infant affect. Mothers will produce context-specific intonation curves over bipolar dimensions of affect when communicating with their 2-month-old infants, in both tone languages such as Chinese Mandarin and stress languages such as American English (Papousek and Papousek, 1991). This suggests that, at least some features of maternal intonation are used across languages to regulate emotional affect in

infants. The problem is, that this is only one tiny piece of the puzzle and the underlying features of the specific intonation contours discussed here, are still not fully understood. What is it about such intonation that provides the vital information to the listener about the speaker's affective message?

Shimura and Imaizumi (1995) found that two-month-old Japanese infants modified aspects of the fundamental frequency in their utterances to express emotional affect. The infants manipulated the fundamental frequency range, intonation contour shape, vocalisation length and altered the number of segments in their vocalisations to express specific emotions. These researchers found that mothers appropriately interpreted the infants' emotional expressions. The mothers responded to the infants based on their interpretations and according to the context, and in this way the infant learns the function of language.

It is accepted that there is co-ordination of structural features of communication, such as fundamental frequency, duration, loudness and pitch, but it is not known how these properties interact. Difficulties lie in the complex involvement and co-ordination of different structural properties of the sounds in speech. An added difficulty is that perception of communication and language involves a great deal more information than is available from the acoustic signal alone (Kuhl and Meltzoff, 1982; Harris et al., 1986; Heinmann, 1998; Papaeliou, 1998). The human infant is born with the motivation for intersubjective communication with others on a multi-model level. Trevarthen (2000) puts it well when he says that infants are "born for a new kind of brain-to-brain interaction and for a unique capacity for cultural learning" (p14). Motivation, and the emotional intention that it induces, are the driving forces for infant attention, perception and action.

Motivations and Meaning

Aitken and Trevarthen (1994, 1997) describe the development of neural systems for the motivation for intersubjective communication in the brain of the human foetus. The neonatal ability to communicate sympathetically with other people is founded on a biological substrate of behaviour. The intrinsic motivation to communicate develops, in a sense, from the inside out (Trevarthen and Aitken, 2000). Newborn infants are innately motivated to "employ poly-rhythmic expressiveness in synchrony with the care and support of their parents to learn the signs of communication in a particular culture" (Trevarthen, 1999, p174). They are born to communicate and to learn.

The musical features of infant-directed speech are known to be perceptually attractive to infants. Infants can discriminate temporal patterns, harmonic intervals, loudness and voice quality (Chang and Trehub, 1977; Chang and Trehub, 1977; Trehub, 1987; Trehub et al., 1993). They show a preference for communication pitched at 262 Hz, which in musical terms is a middle C (Trehub, 1990), and they can differentiate between intonation contours (Papousek, 1996). They do not discriminate on the basis of individual factors; rather their discrimination is based upon individual features in relation to the surrounding features (Cohen et al., 1987). Music and Language are human artefacts and they are both built upon re-occurring patterns (Martin, 1972; Hofstadter, 1985). These patterns range from the simple, as is optimal for infant-directed speech and song (Trehub,

1990 ; Trainor, 1996), to the highly complex, such as the regulation of grammar. These patterns are predictable, they have a beginning and an end, and they allow humans to formulate meaning from acoustic streams of information.

Friederici and Wessels (1993) found that 9-month-old infants show a preference for certain phonotactic patterns that provided information on word boundaries, when words were presented, embedded into a context of similar words. In another experiment these researchers filtered phonotactic information from the speech sample, whilst leaving prosodic information intact. They found that the infants showed no preference for the specific word boundaries. They conclude that it is phonotactic information that provides information to the infant listeners about the prosodic features. Phonotactics are the particular sequences of sounds that are evident in any given language (Crystal, 1992), in other words they indicate the relationship of different aspects of patterns in speech. Other researchers have emphasised the influence of preceding and following sounds, on the sound to be perceived or produced (Chang and Trehub, 1977 ; Trehub et al., 1987 ; Ladd, 1996). When trying to uncover what features of sound infants are attending to (or producing), it is important to consider contextual information.

Communication occurs between people and as well as structural information about sound, there is also an interaction between contextual factors and motivation. The co-ordination of motivation and communication has been shown to play a central role in mutually satisfying communication between parents and their infants (Papousek and Bornstein, 1992 ; Papaeliou and Trevarthen, 1994 ; Reddy et al., 1997). It has been shown that there is some regularity in parent-infant envelopes (Jaffe et al., 1999). They are dynamic, constantly changing and regulated by both partners depending on what they feel and what they want to express (Beebe et al., 1982 ; Beebe and Gerstman, 1984 ; Beebe et al., 1991 ; Papousek, 1992 ; Fernald, 1992).

If the patterns underlying early communicative behaviour can be teased apart, developmental, neuropsychological and cognitive research will benefit greatly. It would provide evidence about what is innate and it can give clear information about what processes are going on at different developmental stages. It could facilitate in understanding whether the brain is firing to separate, distinctive aspects of the overall temporal pattern and if so how these aspects are communicating with each other.

Als (1995) suggests that communicative development is linear. She describes the premature infant as " neurodevelopmentally expecting three securely inherited, evolutionarily promised environments in support of their appropriate development, namely, their mother's uterus, their parent's bodies and their families community and social group " (p440). She states that, the older the infant is when born, the higher the infants' scores will be on attentional, motoric and regulatory organisation scores. This research with premature infants suggests that the full term infant will have an optimal 'expectation' of specific communicative features occurring in their environment.

THE PRESENT RESEARCH

The theories mentioned above and the research behind them shows that communicative systems are organised behaviourally and perceptually. They give much needed detail about how the mechanisms are expressed. However, many questions still remain about

how prosodic features of language are developed and maintained. The present research hopes to carry out a preliminary study of the part that mother/infant vowel sounds have in relation to temporal and prosodic information.

The theory is proposed that phonological and prosodic features of vowels mark primary elements of the co-ordinated and musical interactions that are evident between parents and their infants. There are several reasons for believing that vowels may be marking temporal pattern for infants. They are among the first canonical sounds to be produced by an infant (Locke, 1993 ; Oller, 1986 ; Trevarthen, 1999). Vowels are one of the salient features of speech (Ladd, 1996). Vowels have more extensive harmonics (formants) and infants show a poorer performance on perceptual tasks when harmonic information is limited (Clarkson et al., 1996). It is possible that infants may be drawn to vowel sounds because they are rich in perceptually attractive information. A sensitivity to vowels would correlate with the preference infants show for the affect content of infant-directed speech (Kitamura and Burnham, 1998b).

Vowels play an important part in determining the next sound to be made and in intonation (Ladd, 1996). In this way they are relevant for affect and emotional expression and in the overall narrative of any interaction as well as the articulation of speech. The present study presents this theory in its embryonic stages and provides a brief introduction to further (more extensive) research aimed at establishing precise vowel placement information in speech and singing to infants. Thus the research presented here concentrates on a detailed description of the normal parent-infant interactions in which the vowels are placed in a rhythmic frame.

Theory of Analysis

An analysis of the musical nature of parent-infant communication will provide a basis for continuation of the project to establish the part that vowel sounds play in the expression and perception of emotion and motivation that is central to any mutually satisfying interaction. It will also illuminate the child's path to hearing and producing speech and language.

The pulse / beat, and regulation of rhythms especially duration of seperated phrases will be examined using a combination of methods (discussed above) that have already proved constructive in infant studies. This will provide a necessary backdrop for future research into the placement of vowels in communicative interactions produced by English-speaking and Japanese-speaking parents and infants. A small selection of Short (< 200ms) and Long vowels (200-500ms) will be distinguished and measured with Linguistic software as a test of the proposed method. Spectrographs will act as time maps, showing visually the narrative forms with their expressive changes. These will provide basic data for detailed description of the vocal data.

The pre-semantic envelope and non-referential narrative or drama will be examined using a combination of video microanalysis and acoustic and linguistic methods. Transitions of excitement or tension in segments of spontaneously-produced, contextually relevant speech and nonsense vocal games with and without body movement will be studied to see how parentese in ordinary playful or comforting chat act to 'regulate' infant's emotions. Video microanalysis will be combined with the spectrographic investigation to

give a comprehensive description of the some of the ways in which communication is co-ordinated and regulated over time.

Research Aims

(1) To provide a precise description of normal parameters in samples of good vocal communication between mother and infant, during interactions, in songs, or rhythmic games.

(2) To collect evidence of features of mother's voice and expression and of infant's response that may be universal, looking especially at the rhythmic/narrative structure and acoustic patterns.

(3) To determine some of the ways in which the mother gives affective emphasis to the content of her speech and song.

(4) To establish the temporal pattern of vocal and non-vocal communicative interactions and provide a methodology that will form the basis of future examination of the timbral aspects of vowel structure and vowel placement in the rhythmic structure of the overall narrative in mothers' talk to infants.

Predictions

(1) I predict that an examination of the normal parameters of good communication will show that a mutually satisfying interaction will be built upon the features of musicality as described by Malloch (1999).

(2) I predict that there will be a variety of phonological and prosodic features that are salient to the infant and manipulated by the parent that will be recognisable in all healthy interactions. This suggests some universal features that will be the focus of future study with English-speaking and Japanese-speaking parents and infants.

(3) I predict that there will be co-ordinated temporal regulation of communication between mother and infant. It is expected that future study will reveal that both in the mother's speech and in the infant's imitative vocalisations, presentation, synchronisation and imitation of vowels will play a major role in marking the temporal patterning of phrases in interactions, and show how they will be used as a principle means by which temporal aspects of expression of emotional affect is regulated both by parent and infant.

METHOD

Subjects

Seven mother-infant pairs volunteered to take part in the project. They were informed that the study was for the purpose of gaining a description of parent-infant vocalisations. All of the mothers were English-speaking and they all lived with their husbands or partners. Confidentiality was assured, and the mother's written permission was obtained for using film and DAT recordings of their interactions for research purposes. Mothers were given a copy of their own video to keep.

Each pair were filmed and recorded once every two weeks over a period of three months. Due to illness and holidays, filming/recording sessions where not always every 14 days. The range of difference in time between filming is shown in figure 1 below:

Filming sessions took place in the mother and infants' home. They were arranged

Table 1 Infant Identification Code and Gender.

JAK	HO	IS	JAN	RO	AI	LI
MALE	FEMALE	MALE	FEMALE	FEMALE	MALE	FEMALE

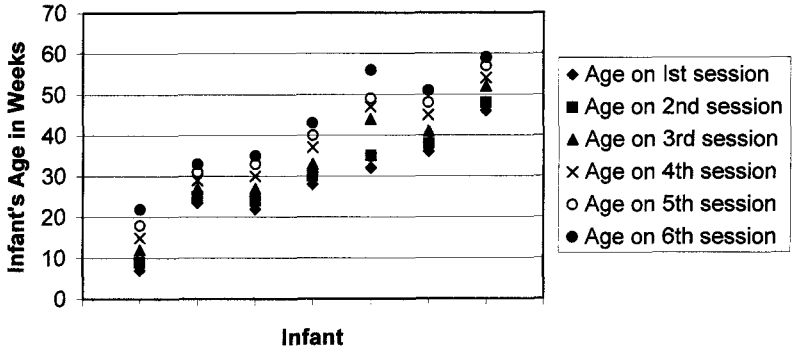

Figure 1 Age of Infant at each filming session.

to be at a time when each infant was rested and had been fed. Recording equipment was set up and the mother and infant were given time to habituate to the camera. They were asked to play as they normally would. Each session lasted for 20minutes.

Analytic Procedure

All of the videos were first pre-viewed in their entirety to get an idea of the relationship between each mother and her infant. The events during each session were noted. Special attention was given to the points at which the infants vocalised. One-minute segments were chosen from each session, for each mother-infant pair. The segments contained samples of spontaneous communicative interaction, and either child-directed song or rhythmic vocal play. The main criterion for inclusion of a segment was defined as a period during the session where both partners are contributing vocally. Where possible recording of each segment was initiated at the beginning of a 'narrative event' that contained vocal contributions from both partners. A narrative event is a sequence of actions or behaviours that can be perceived as having a beginning, middle and an end. Recording was stopped after one minute.

Microanalysis of Video Data

Microanalysis of the video data was carried out to examine unambiguous, verbally defined categories for the infants. Co-ordinated expression, movement and affect were the main parameters for close examination. A validated category system (Trevarthen and Marwick, 1982) was used. The use of this system allowed detailed description of the communicative behaviours that occurred between each mother and her infant over the three-month period.

A one-second time-interval was the unit of microanalysis. Behaviours were coded and graphically represented for each infant. A behavioural category was defined as occurring when it was evident for at least 500ms. To ensure that coding was valid, a researcher who was unfamiliar with the Communicative Musicality Model and who is from

an entirely different theoretical discipline (Business Management) was given a short training session in the coding system. The system was demonstrated once to the volunteer, and then she practiced several times asking questions until she felt confident that she understood the categories and familiarised herself with the equipment. She was then left alone to re-code samples chosen at random. She coded 15% of all data sheets and scores for each sample were compared, the mean of all scores was calculated and inter-rater reliability was established at 87.8%.

Acoustic Analysis

Acoustic analysis was carried out on the initial segments of the first session recorded for each infant, to make clear how the mother is giving emphasis to the affective features of her communication. Only the first segment was used in this initial test of the method. The idea was to separate temporal features (rhythm) from pitch and quality and to chart the development of narrative progressions in expression. To do this, corresponding DAT recordings for each segment were transformed into wave files and then recorded onto re-writable CDs to allow the sound files to be easily transportable and as a means of managing the large files involved. Wave files were created using SoundForge 4.5 PC software. This software allows the sound file to be analysed whilst it is being listened to.

The wave files were then analysed using Hypersignal PC software (Malloch, 1997). This software is based on methods described by Brown (1991, 1992) and it produces spectrographs of the acoustic data permitting segmentation of temporal features from pitch and quality. This gives a clear picture of how the mother is giving emphasis to affective features of her communication (bridge between speech and song) and enables a clear description of the overall rhythmic structure of the interactions.

Linguistic Analysis

Spectral compositions of the vowels produced by both mother and infant were compared with the aid of Praat software. Strong-weak syllables (were the stress is on the consonant and the vowel is weaker) or single vowel sounds taken from the chosen segments were subjected to a primary pitch, intensity and formant analysis.

The present study provides a brief introduction to formant analysis of the vowel sounds. Analysis of formant patterns (especially patterns found in fundemental and first formants) is useful because it is information provided to the listener in these formants that allows discrimination of vowels and identification of the next sound to be made (Crystal, 1992).

The Praat program applied a spectro-temporal analysis using parameters of time step (in the present case this was set at 0.01sec), maximum number of formants (this was set at 5, the normal adult range) and pre-emphasis frequency (50 Hz). The latter is an algorithm that calculates the value of each sample period of sound to reflect (and in relation to) the sound sample before it. This program was used to look at mother's imitations and matching of infant vowel sounds enabling an examination of the quality aspect of the sound.

RESULTS

General Findings

A detailed case study was built up for each mother and her infant. This allowed a precise description of vocal and non-vocal communication for each pair. A small sample of the data will be used to illustrate the findings.

Table 2 below, shows the overall cumulative frequencies of communicative behaviours shown by video analysis for each infant, over the three months of the filming period. Table 2 shows that negative arousal states, avoidance, self-directed behaviours and recalcitrance decrease as the infants' ages increase. Playful behaviours involving objects, such as co-operative games, increase with the age of the infants. Table 2 also allows a comparison between individual infants.

It is important to mention some general points for consideration. During data collection some 'expectancy effect' was evident in the subjects' behaviour. Mothers often worked quite hard to elicit vocalisations from their infants and expressed concern if

Table 2 Overall Frequencies of Video Analysis Behaviours.

Behavioural Categories	Infants (Age range in Weeks)						
	JAK	HO	IS	JAN	RO	AI	LI
	(7-22)	(23-33)	(22-35)	(28-43)	(32-56)	(36-51)	(46-59)
arousal 1	50	17	43	37	12	4	
arousal 2	200	303	317	323	341	356	359
arousal 3	59	40			4		1
arousal 4	19				3		
positive affect	160	323	326	326	342	360	356
neutral affect	165	16	28	30	11		4
angry					2		
anxious							
sad	24	11	5		5		
attend face	57	31	52	46	54	30	47
attend hands	263	312	285	294	301	330	309
avoid	30	17	23	11	5		4
playful	164	338	329	339	342	360	354
recalcitrant	175	22	22	21	18		6
utterances	46	57	69	87	63	58	75
prespeech	24	109	69	75	155	94	132
exploratory/performative	162	341	317	315	356	356	352
self-directed	2	9	53	36	14		
imitates		4	3	3	12		
try			2	1	25		
track		148	150	102	80	149	156
reach/hunt	31	238	239	121	154	222	194
prereach			1				14
cooperative transfer				1		6	6
cooperative game			6	58	38	44	94

their infants were quiet. This, however, did not cause them to deviate greatly from their normal communications with their child. All of the mothers demonstrated joy and fascination when their infant smiled or made any other overt communicative gestures, whether they were being filmed or not. The mothers seemed to grow less aware of the camera over the time of filming (none of them felt comfortable singing in the first session), whereas the infants seemed to become more aware of it.

Although the mothers had individual differences in parenting methods and styles, they all shared some general similarities. They all adopted the characteristics of motherese 'infant-directed' speech. They exaggerated their intonation, and pitch range and they used simpler words that they repeated often. They all gave verbal explanations of their own actions and the actions of their infants. All of the mothers demonstrated actions and the use of toys for their infant. They exaggerated and slowed down their movements, often vocally producing the noise made by the animal or toy. They all asked their infants questions for example, every mother asked their infant at some point during the filming "are you telling a story?" and many other questions were asked to enquire about what the infants were doing at that point, giving insight into the mothers' interpretations of the infants' actions and affective states.

All of the mothers gave constant assessment of or investigation into their infant's motives and emotional states, and they changed their communicative patterns to maintain a positive affective balance. Most of the time the mother's attribution of an emotional state appeared to be appropriate and it seemed that the infants were skilled in regulating their mother's attention depending on their emotional needs at any given time. The type of instruction/communication changed as the infant developed.

All mothers imitated the vocalisations made be their infants. That is, they matched the sound, sometimes exaggerating it (by lengthening the vowel sounds) or repeating it several times. They also imitated facial expressions, hand gestures and actions. The infants produced language specific stress patterns and preliminary formant analysis indicated that there are interesting structural properties of their utterances, that change over time.

All of the infants had individual differences in behavioural patterns and personalities, but they also demonstrated similarities in some features of their communicative attempts. For example, they all exhibited a sense of humour. They all performed for the researcher, showing off their tricks, smiling and flirting. They all developed an overt interest in the camera and recording equipment as the sessions went on. All of the infants produced avoidant behaviour when the mothers' responses were non-contingent.

Both mother and infant altered their communication depending on how they felt, for example if they were tired. All of the mothers spent time just quietly watching their infant chatting or playing and they all smiled whilst doing so. The mothers varied as to how much time they spent doing this, some hardly did it at all while others spent long periods during the filming session quietly watching their infant. This was particularly evident as the infants got older and began to show more autonomy and interest in objects.

There was a lot of evidence to suggest that communicative behaviours were temporally organised. Communicative behaviours do not remain rhythmically constant. They appear to form a dynamic, functional system that is adapted and regulated by both mother

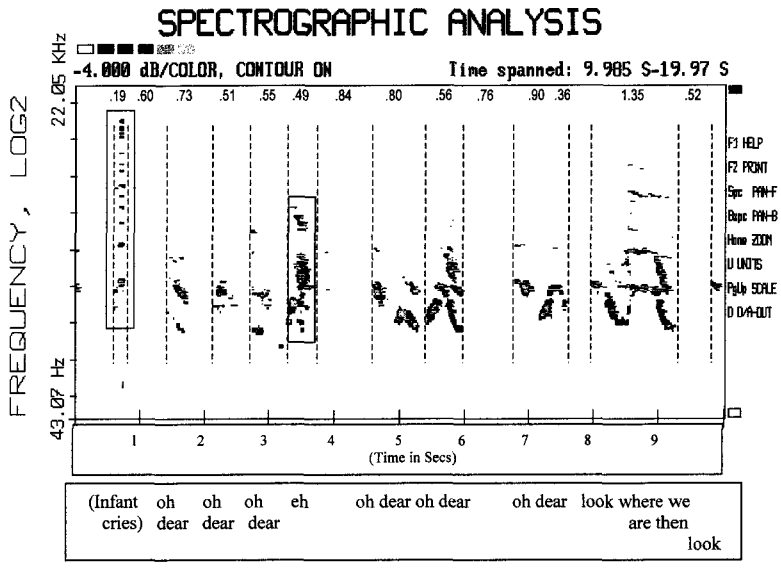

Figure 2 Spectrographic Analysis for JAK.

and infant, to express and maintain positive emotional affect. Complete spectrographic analysis was carried out for each mother and child. Spectrographic examples are shown below. Temporal patterns were measured and are shown by the vertical lines. Infant vocalisations are marked with boxes.

The spectrograph shown in figure 2 gives an example of the temporal regularities found in all of the communication that was examined. This spectrograph shows communication between a mother and her 7-week-old son. The infant cries and the mother uses a repeated intonational pattern to try and sooth her infant. Her overall temporal pattern has many regularities and her intonation contour falls to indicate completion of each unit in the sequence. The infant's cry and his vocalisation (in the first 4 seconds of the spectrograph) when combined measure the same as the mother's general pattern. This indicates that he has some representation of the temporal pattern established earlier in the interaction by his mother and has some ability to match it. His mother has established her temporal pattern in an effort to maintain positive affect in her son. She repeats a simple pattern, producing combinations of rhythmical units in response to his emotional message. The temporal pattern is formed around pauses and vocalisations and it appears that both mother and infant vowel sounds give saliency to the rhythmical units of the interaction.

Figure 3 shows a 23-week-old infant vocalising with her mother. The spectrograph shows how vocal communication for this mother-infant pair is structured around a rhythm that is established by the mother making clicking noises with her tongue. The infant vocalises in the third second of the spectrograph, producing a vowel sound with recognisable formants. Her temporal pattern is a division of the pattern her mother sets and her intonation falls slightly at the end as if to complement the rhythmical structure that is already established. When the infant vocalises, her mother leaves a pause of the same length as the infant's vocalisation and then in the fourth second of the spectrograph she produces an extended vowel sound, also recognisable by its layers of formants. The

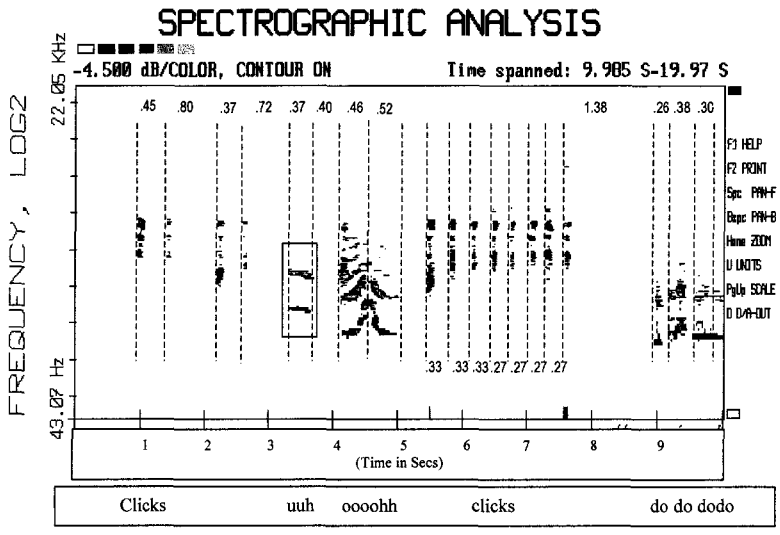

Figure 3 Spectrographic Analysis for HO.

mother's vocalisation takes the form of a reply to her infant's sound and it matches the frequency of the infant's sound.

The preliminary analysis of vowel sounds suggested that vowels are placed at key points throughout the overall speech stream. Mothers lengthened their vowel sounds and when their intonation was exaggerated, it was the vowel sounds that provided the basis for this exaggeration. Infants produced strong vowel sounds that were strongly associated with the expression of emotional affect. However, a comprehensive examination showing the exact phonological and temporal information is beyond the scope of the present research and it is hoped that this will be examined in future research with English-speaking and Japanese-speaking dyads.

DISCUSSION

The findings of the present research support many of the theories presented in the introduction. In particular, the Communicative Musicality Model (Malloch, 1997, 1999) is shown to be a viable and useful method that has potential use in both descriptive and quantitative research. The present research also confirms Malloch's findings that the mothers are acting to maintain a " balance in their joint exploration of pitch space " (1999, p40).

Imitation of infant vocalisations was evident in all of the mother-infant pairs in the present study. This was independent of the infant's age and was apparent in all of the sessions. The mother's imitations of the infant's vocalisations appear to have some kind of representational purpose. Exaggerations and repetitions reinforce the original sound to the infant and this often resulted in the infant attempting to make the same sound again. The infants sometimes imitated the mother's exaggeration of their original sound. This may in some way strengthen neural connections that help them to establish language specific stress patterns in a simple (syllabic) form in the infant's brain.

Research by James Morgan (1995, 2000) demonstrated that infants who were

exposed to English between the ages of 6 and 9 months, showed a preference for the strong-weak stress pattern characteristic of English prosody. The infants showed this preference for both syllabic and word boundaries. Before the age of 6 months, Morgan found that the infants showed no preference. Cutler (2000) also found that infants had no preference for language-specific prosody before the ages of 6 months. Her work was a part of an international project that aimed to give description of the 'Music within words', comparing prosodic features in Belgium, Canada, France, the Netherlands, Spain and Britain. In an interesting experiment she filtered the acoustic signal presented to infants, leaving only prosodic information. Infants around the age of 9 months continued to show a preference for their mother tongue. Cutler concluded that infants are relying on prosodic features for identification of boundaries.

Mehler (2000) worked on the same project and he found that French neonates at the age of 3 days could distinguish the prosodic breaks at word level. The infants could detect prosodic features from French and Spanish. Both of these languages have very different prosodic structures. For example, French prosody stresses the last syllable in a word, whereas in Spanish prosody, stress changes with each word (to determine it's meaning) and pitch is also used to mark word endings. Mehler suggests that the neonates have an innate capacity to detect prosodic features of all languages and that some development occurs between the ages of 6 and 9 months that will focus their attention onto specific prosodic features characteristic of their own language.

Research has shown that linguistic experience has placed constrictions on infants' abilities to perceive phonetic constituents of speech (Kuhl, 1998). By the age of 6 months, the infant's brain will have become more selective in the phonetic characteristics that it can distinguish. The present study provided evidence that several factors were interacting at this stage in development. Vocal utterances became more advanced, the infants produced language specific stress patterns, they became increasingly mobile and much more aware of a larger environmental space.

It is during this period that secondary intersubjectivity is developed. The present research provided a wealth of evidence to support the idea that infants begin to take initiative in co-operative games around the age of 9 months (Trevarthen and Hubley, 1979; Trevarthen, Murray and Hubley, 1981). The mothers reacted to this development by taking more of a back seat. They sat quietly watching and smiling as their infants directed the play, demonstrating toys only when requested to do so by the infant, or when the infant was in obvious difficulty. Play with objects became more central in the interactions.

Six-months is also the period when the normally developing infant will begin to 'perform' for others (Trevarthen, 1994). All of the infants in the present study were progressively more interested by the researcher and the filming equipment. For some of the infants the last sessions were characterised by repeated attempts to get close to, and explore, the camera. All of the infants displayed a strong awareness of, and a desire to communicate with, the researcher. They all displayed anxiety when their communicative attempts were ignored because the researcher was too busy filming (or did not want to distract the infant from communication with the mother), and did not respond. As they developed, the infants displayed more flirting behaviour and increased the time they spent

looking at the camera. They often involved the researcher in their games and the researcher in turn, often became caught up in the temporal co-ordination of the interaction. This is not surprising however, and serves as an indication of the infants' desire to communicate (Trevarthen, Murray and Hubley, 1981) and the importance of contingent responses for infant well being (Murray, 1992; Robb, 1999).

All of the mothers in the present study produced more exaggerated intonation when they were talking to their infants and they moderated the timing of their vocal and non-vocal communicative behaviour based on their infant's behaviour. The mothers seemed to work to maintain an optimum level of affect (Malloch, 1999; Trevarthen, 2000).

My findings on vowels are, at present limited and will involve further study before they can be subject to a valid comparison with linguists characterisations of the language as to timing of stresses, vowel complexity, tones and vowels. The present findings provide a lot of evidence to support the idea of Wittman and Poppel's high / low frequency temporal fundamentals. However, the results also suggest that the idea of a neuronal clock is perhaps too rigid a description for the complex processes that are occurring on many levels. Descriptions gained in the present study suggest that various emotional factors have to be taken into consideration. It may be that the 30ms / 3s serves as a common optimum level to which the dyads work to maintain but more detailed description is needed of the dynamics of expression before the coordination of vocalisations in time can be explained.

Questions Still Remainin

Further study is intended to address some of the many questions that still remain. Acoustic analysis needs to be extended further over a wider sample of the present mother-infant communications. A more detailed pitch and timbral analysis is required to understand how maternal vowels are utilised and how this changes with the development of each infant and to reveal the ways in which maternal vowel use changes as the infants get older. Infant vowel production and the ways in which infants manipulate their vowel production to express their affect and to draw their mother's attention to more subtle aspects of their communication, also requires a more detailed examination over time.

Practical Application of Communicative Musicality

There are many practical applications of the Communicative Musicality method. It is a useful tool in many research settings were detailed examination of communicative interactions is necessary. The model allows an objective visual description of normal communication and highlights the complex patterns that create meaning in communication. The method can be usefully applied for determining when there are developmental delays in communicative ability. This method can highlight the precise areas in which an individual may have difficulties and so could be used to look at communication between parents, carers and teachers and the children in their care.

The method has been used successfully, to highlight other difficulties in mother-infant relationships, such as postnatal depression (Murray, 1992; Robb, 1999) and acculturation (Gratier, 1999). The method has shown precisely how communication is altered when the mother's mental health or state of well being is challenged, and this would

allow it to be used in a clinical (preventative and etiological) setting. Those who work in a therapeutic situation where verbal/non-verbal therapies are important (Coulter and Loughlin, 1999) have expressed interest in using the model to gain more understanding of how therapy works, or how it can be improved (Loughlin, 2000).

Conclusions

Conclusions can be drawn about the nature of early communication and the intersubjective foundations for learning meaning and language. Normal interactions between parents and their infants are characterised by complex dynamic interactions between different modalities. These interactions are driven by intersubjective motivation to participate in communication that allows both partners to anticipate the other's motives and allow contributions from both partners

It can also be concluded that the Communicative Musicality Method is a useful descriptive tool. It allows a comprehensive and detailed analysis of acoustic data that is necessary when trying to describe something as rich and complex as communication.

The present findings show that normal mother-infant communication requires both partners to actively assess and regulate the other, on an overall temporal level and at a more specific phonological level.

Acknowledgements

I would like to thank the mothers and babies who volunteered to take part in this study for their cheerful participation and their interest in my study. I would also like to thank my Supervisor Professor Colwyn Trevarthen for his support, his inspirational insights into the subject area and for his sharp intelligence. I am very grateful to Rhys Pendred, Stevie and Joe and to my Family for putting up with my preoccupation with this project,. I would also like to thank Jacqueline Holms who worked efficiently and precisely coding my videotapes. There are many other people (especially in the Department of Psychology at The University of Edinburgh) who supported and advised me during this research project and I would like to say thank you to everyone who helped.

REFERENCES

Aitken, K. J. and Trevarthen, C. (1994). Brain Development, Infant Communication, and Empathy Disorders: Intrinsic Factors in Child Mental Health. *Development and Psychopathology, 16*, 597-633.

Aitken, K. J. and Trevarthen, C. (1997). Self-Other Organisation in Human Psychological Development. *Development and Psychopathology, 9*, 651-675.

Als, H. (1995). The Preterm Infant: A Model for the Study of Fetal Brain Expectation. In J-P. Lecanuer, W. Fifer, N. A. Krasnegor, W. P. Smotherman (Eds.), Fetal Development. A Psychobiological Perspective. Hove: Lawrence Erlbaum Associates Publishers.

Beebe, B., Gerstman, L., Carson, B., Dolins, M., Zigman, A., Rosensweig, K. F. and Korman, M. (1982). Rhythmic Communication in the Mother-Infant Dyad. In M. Davies (Ed), Interaction Rhythms. New York: Human Sciences Press.

Beebe, B. and Gerstman, L. (1984). A Method of Defining 'Packages' of Maternal Stimulation and Their Functional Significance for the Infant with mother and Stranger. *International Journal of Behavioural Development, 7*, 432-440.

Beebe, B., Jaffe, J., Feldstein, S. and Crown, C. L. (1991). Mother-Infant Rhythms of Dialogue.

Presented at the Symposium on Interactional Rhythms. Washington.

Brown, J. C. (1991). Calculation of a Constant Q Spectral Transform. *Journal of the Acoustical Society of America, 89*, 425-434.

Brown, J. C. (1992). Musical Fundamental Frequency Tracking Using Pattern Recognition Method. *Journal of the Acoustical Society of America, 2*, 1394-1402.

Chang, H-W. and Trehub, S. E. (1977). Infants' Perception of Temporal Grouping in Auditory Patterns. *Child Development, 48*, 1666-1670.

Chang, H-W. and Trehub, S. E. (1977). Auditory Processing of Relational Information by Young Infants. *Journal of Experimental Child Psychology, 24*, 324-331.

Clarkson, M. G., Martin, R. and Miciek, S. G. (1996). Infants' Perception of Pitch: Number of Harmonics. *Infant Behaviour and Development, 19*, 191-197.

Cohen, A. J., Thorpe, L. A. and Trehub, S. E. (1987). Infants' Perception of Musical Relations in Short Transposed Tone Sequences. *Canadian Journal of Psychology, 41*(1), 33-47.

Coulter, H. and Loughlin, E. (1999). Synergy of Verbal and Non-Verbal Therapies in the Treatment of Mother-Infant Relationships. *British Journal of Psychotherapy, 16* (1), 58-73.

Crystal, D. (1992). The Cambridge Encyclopaedia of Language. Cambridge: Cambridge University Press.

Cutler, A. (2000). Findings reported in: http://www.cog.brown.edu/~morgan/

DeCasper, A. J. and Fifer, W. P. (1980). Of Human Bonding: Newborns Prefer Their Mother's Voices. Science, 208, 1174-1176.

Fernald, A. (1992). Meaningful Melodies in Mothers' Speech to Infants. In H. Papousek, Jurgens, U. and M. Papousek, (Eds.), Nonverbal Vocal Communication., 209-229. Cambridge: Cambridge University Press.

Fifer, W. P. and 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. Hove, UK.: Lawrence Erlbaum Associates Publishers.

Friederici, A. D. and Wessels, J. M. I. (1993). Phonotactic Knowledge of Word Boundaries and it's Use In Infant Speech-Perception. *Perception and Psychophysics, 54* (3), 287-295.

Gratier, M. (1999). Expressions of Belonging: the Effect of Acculturation on the Rhythm and Harmony of Mother-Infant Vocal Interaction. *Musicae Scientae*, Special Issue 1999-2000, 93-122.

Harris, M., Jones, D., Brookes, S. and Grant, J. (1986). Relations Between the Non-Verbal Context of Maternal Speech and Rate of Language Development. *British Journal of Developmental Psychology, 4*, 261-268.

Heimann. M. (1998). Imitation in Neonates, in Older Infants and in Children With Autism: Feedback to Theory. In Stein Braten (Ed.), Intersubjective Communication and Emotion in Early Ontogeny. Pp.89-104. Cambridge: Cambridge University Press.

Hofstadter, D. R. (1985). Metamagical Themas: Questing for the Essence of Mind and Pattern. Harmondsworth: Penguin Books.

Hubley, P. and Trevarthen, C. (1979). Sharing a Task in Infancy. *New Directions for Child Development, 4*, 57-80.

Jaffe, J., Beebe, B., Feldstein, S., Crown, C. and Jasnow, M. (1999). Rhythms of Dialogue in Infancy: Co-ordinated Timing and Social Development. (Submitted to SRCD Monographs February 1999).

Kitamura, C. and Burnham, D. (1998). The Infant's Response to Maternal Vocal Affect. (C. Rovee-Collier, L. P. Lipsitt and H. Hayne (Eds.), Advances in Infancy Research, 12, 221-236. Stamford: Ablex.

Kuhl, P. K. and Meltzoff, A. N. (1982). The Bimodal Perception of Speech in Infancy. *Science, 218*, 1138-1141.

Kuhl, P. K. (1998). Language, Culture and Intersubjectivity: The Creation of Shared Perception. In Stein Braten (Ed.), Intersubjective Communication and Emotion in Early Ontogeny. Cambridge University Press.

Ladd, D. R. (1996). Intonational Phonology. Cambridge: Cambridge University Press.

Locke, J. L. (1993). The Child's Path to Spoken Language. Cambridge MA: Harvard University Press.

Loughlin, E. (2000). Personal Communication.

Malloch, S., Sharp, D., Campbell, D. M., Campbell, A. M. and Trevarthen, C. (1997). Measuring the Human Voice: Analysing Pitch, Timing, Loudness and Voice Quality in Mother-Infant Communication. *Proceedings of the Institute of Acoustics, 19* (5), 495-500.

Malloch, S. N. (1999). Mothers and Infants and Communicative Musicality. *Musicae Scientae.* Special Issue 1999-2000, 29-57.

Martin, J. G. (1972). Rhythmic (Heirarchical) Versus Serial Structure in Speech and Other Behaviour. *Psychological Review, 79* (6), 487-509.

Mehler, J. (2000). Findings reported in: http://www.cog.brown.edu/~morgan/

Morgan, J., Saffran, J. R. (1995). Emerging Integration of Sequential and Suprasegmental Information in Preverbal Speech Segmentation. *Child Development, 66*, 911-936.

Morgan, J. (2000). http://www.cog.brown.edu/~morgan/

Murray, L. (1992). The Impact of Postnatal Depression on Infant Development. *Journal of Child Psychology and Psychiatry, 34*, 1083-1101.

Oller, D. K. (1986). Metaphonology and Infant Vocalisations. In B. Lindblom and R. Zetterstrom (Eds.), Precursers of Early Speech. Pp.21-35. Basingstoke: Macmillan

Papaeliou, C. and Trevarthen, C. (1994). The Infancy of Music. *Musical Praxis, 1* (2), 19-31.

Papaeliou, C. (1998). Infant Prosodic Expression in Mother-Infant Communication. PhD Thesis. University of Edinburgh.

Papousek, M. and Papousek, H. (1991). The Meanings of Melodies in Motherese in Tone and Stress Languages. *Infant Behaviour and Development, 14*, 415-440.

Papousek, H. and Bornstein, M. (1992). Didactic Interactions: Intuitive Parental Support of Vocal and Verbal Development in Human Infants. In H. Papousek, Jurgens, U. and M. Papousek (Eds.), Nonverbal Vocal Communication, Pp.209-229. Cambridge: Cambridge University Press.

Papousek, M. (1992). Early Ontogeny of Vocal Communication in Parent-Infant Interactions. In H. Papousek, Jurgens, U. and Papousek, M (Eds), Nonverbal Vocal Communication. Pp.209-229. Cambridge University Press.

Papousek, H. (1996). Musicality in Infancy Research: Biological and Cultural Origins of Early Musicality. In Irene Deliege & John A. Sloboda (Eds.) Musical Beginnings: Origins and Development of Musical Competence. Oxford: Oxford University Press.

Reddy, V., Hay, D., Murray, L. and Trevarthen, C. (1997). Communication in Infancy: Mutual Regulation of Affect and Attention. In G. Bremner, A. Slater and G. Butterworth (Eds.), Infant Development: Recent Advances. Pp.247-274. Hove: Psychology Press.

Robb, L. (1999). Emotional Musicality in Mother-Infant Vocal Affect, and an Acoustic Study of Postnatal Depression. *Musicae Scientae*, Special Issue 1999-2000, 123-154.

Shimura, Y. and Imaizumi, S. (1995). Emotional Information in Young Infants' Vocalisations. *Proceedings ICPhS, 3*, 412-415.

Spence, M. J. and Freeman, M. S. (1996). Newborn Infants Prefer the Maternal Low-Pass Filtered Voice, But Not the Maternal Whispered Voice. *Infant Behaviour and Development, 19*, 199-212.

Stern, D. N., Spieker, S. and MacKain, K. (1982). Intonation Contours as Signals in Maternal Speech to Prelinguistic Infants. *Developmental Psychology, 18* (5), 727-735.

Trainor, L. J. (1996). Infant Preferences for Infant-Directed Versus Non-Infant Directed Playsongs and Lullabies. *Infant Behaviour and Development, 19*, 83-92.

Trevarthen, C. and Hubley, P. (1978). Secondary Intersubjectivity: Confidence, Confiding, and Acts of Meaning in the First Year. In A. Lock (Ed.), Action, Gesture and Symbol: The Emergence of Language., 183-229. London: Academic Press.

Trevarthen, C., Murray, L. and Hubley, P. A. (1981). Psychology of Infants. In J. Davis and J. Dobbing (Eds.), Scientific Foundations of Clinical Paediatrics (2nd Edition), Pp.235-250. London:

W. Heinemann Medical Books.

Trevarthen, C. and Marwick, H. (1982) A Method for Analysing Mother-Infant Communication. From: "Cooperative Understanding in Infants"; Unpublished Project Report to the Spencer Foundation, Chicago. Department of Psychology, The University of Edinburgh.

Trevarthen, C. (1999). Musicality and the Intrinsic Motive Pulse: Evidence from Human Psychobiology and Infant Communication. *Musicae Scientae*, Special Issue 1999-2000, Pp.155-211.

Trevarthen, C. and Aitken, K. J. (2000). Infant Intersubjectivity: Research, Theory and Clinical Application. Annual Research Review, JCPP.

Trevarthen, C. (2000). Intrinsic Motives for Companionship in Understanding: Their Origin, Development and Significance for Infant Mental Health. *Infant Mental Health Journal, 22* (1), 95-131.

Trehub, S. E., Thorpe, L. A. and Morrongiello, B. A. (1987). Organisational Processes in Infants' Perception of Auditory Patterns. *Child Development, 58*, 741-749.

Trehub, S. E. (1987). Infants' Perception of Musical Patterns. *Perception and Psychophysics, 41* (6), 635-641.

Trehub, S. E. (1990). The Perception of Musical Patterns by Human Infants: the Provision of Similar Patterns by Their Parents. In Mark A. Berkley, William C. Stebbins (Eds.), Comparative Perception: Volume 1, Mechanisms. New York: Wiley.

Trehub, S. E., Trainor, L. J. and Unyk, A. M. (1993). Music and Speech Processing in the First Year of Life. *Advances in Child Development and Behaviour, 24*, 1-35.

Wittman, M. and Poppel, E. (1999). Temporal Mechanisms of the Brain as Fundamentals of Communication:With Special Reference to Music Perception and Performance. In: *Musicae Scientae*. Special Issue 1999-2000, Pp.13-28.