

***THE TEMPORAL STRUCTURE OF
MOTHER-INFANT INTERACTIONS
IN MUSICAL CONTEXTS***

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for Peter

DECLARATION

I declare that this thesis has been composed by myself and that the research reported here has been conducted by myself unless otherwise indicated.

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ABSTRACT

The aim of this study is to investigate the nature of temporal structure in mother-infant interactions in musical contexts. Although in the last decade there has been an increase of interest in infant perception of music and maternal singing, little is known about the nature of mother-infant interaction in contexts where mothers sing or play taped music to their infants. This research has several foci: 1) to examine the tempos used by mothers in songs and taped music, as well as the temporal structure of the mothers' songs, paying particular attention to metrical and phrasing structure; 2) to measure the amount and kinds of behaviours produced by the partners of the dyad during musical interaction, with attention to their level of activity and their cyclical behaviours, as well as their communicative-affective behaviours and the infants' emotional states and degree of engagement; 3) to analyse the extent and precision of the partners' synchronisation of their behaviours with self, the musical beat and the other partner; 4) to compare the results of interactions based around songs with those based around taped music. This is an exploratory study which applies a qualitative, micro-analytic observational method to 4 mother-infant dyads: two English-speaking mothers (ES) and two Gaelic-speaking mothers (GS). Two datasets of musical interactions are examined in detail. One includes interactions based around songs and was obtained by asking mothers to sing songs to their 3-4 month-old infants in two contexts: no-touch (where they were asked not to touch their infants) and touch (where they were permitted to touch their infants), and to sing to their 7-8 month-olds in the touch context. The second dataset includes interactions based around taped music and was acquired by asking mothers to play to their 4-5 month-old infants what they considered to be the infant's favourite music and their own favourite music in two contexts: no-touch and touch. One of the most important discoveries from the thesis is with respect to hierarchical structure. A detailed analysis of the temporal structure of the songs revealed that mothers emphasise the metrical and phrasing structure of their songs, acoustically through their singing. In doing so, they provide for their infants a means of segmenting the flow of the song, much as they do with respect to the segmentation of speech. Second, musical tempo turned out to play a more important role than context and age. Mothers do not use a consistent tempo in musical interaction with their infants. Rather, they use a variety of tempos, the most common of which are *andante* (medium) and *allegro* (fast) tempos. It is argued that these may have different functions. The *allegro* tempo may serve the function of attracting and maintaining the infant's attention, whereas the *andante* tempo may be used for more interactional purposes so as to set the pace of the interaction at a natural tempo, i.e., neither too slow nor

too fast. The results for mother-infant interaction during taped music suggest that interactions with the infant's favourite music share more in common with interactions based around live songs than interactions with the mother's favourite music. Overall, the thesis highlights the importance of mother-infant interaction in musical contexts, and suggestions for future experimental studies emerge from the qualitative data which should further our understanding of this vital area of infant development.

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TABLE OF CONTENTS

Title	i
Dedication	ii
Declaration	iii
Abstract	iv
Acknowledgments	vi
Table of contents	vii
Chapter 1 - Temporal organisation in mother-infant interactions in musical contexts	2
1.1 The organisation of tempo in human life	3
1.1.1 <i>Tempo and Rhythm and their theoretical implications for psychology</i>	3
1.1.2 <i>Temporal organisation and its psychological implications for infant development</i>	6
1.1.3 <i>Temporal organisation and its psychological implications for mother-infant interaction</i>	12
1.1.4 <i>Synchrony in mother-infant interaction</i>	17
1.2 Music in human life	20
1.2.1 <i>Music and its implications for infant development</i>	24
1.2.2 <i>Music and its implications for mother-infant interaction</i>	28
1.2.2.1 <i>Infant-directed singing</i>	28
1.2.2.2 <i>The use of playsongs</i>	30
1.2.2.3 <i>Why caregivers sing</i>	31
1.2.2.4 <i>The communicative function of music</i>	32
1.2.2.5 <i>A theory of Innate Musicality</i>	34
1.2.2.6 <i>Mother-infant interaction: from temporal organisation to music</i>	36
1.3. Aims of the thesis	37
1.4 Structure of the thesis	39

Chapter 2 – Methodology	41
2.1 Setting of the research	41
2.1.1 <i>Design and procedure</i>	43
2.2 Coding the data	46
2.2.1 <i>Overview of coding</i>	46
2.2.2 <i>Coding the mother's and infant's physical and communicative-affective behaviours</i>	47
2.2.2.1 <i>The mother's physical behaviours</i>	48
2.2.2.2 <i>The mother's communicative-affective behaviours</i>	49
2.2.2.3 <i>The infant's physical behaviours</i>	49
2.2.2.4 <i>The infant's communicative-affective behaviours</i>	50
2.2.2.5 <i>Coding procedure</i>	50
2.2.2.6 <i>Inter-rater reliability for the mother's and infant's behaviours</i>	52
2.2.3 <i>Coding the musical beat</i>	53
2.2.3.1 <i>Identification of the musical beat</i>	54
2.2.3.2 <i>Musical score and beat</i>	54
2.2.3.3 <i>Inter-rater reliability of the tapped beat</i>	54
2.2.4 <i>Coding the infant's emotional state and degree of engagement</i>	55
2.2.4.1 <i>Setting and procedure</i>	55
2.2.4.2 <i>Inter-rater reliability of the infant's emotional states and degree of engagement</i>	56
2.3 Analysis of musical interaction	57
2.3.1 <i>Analysis of the mother's and infant's physical and communicative-affective behaviours</i>	57
2.3.1.1 <i>Mother's and infant's physical behaviours</i>	57
2.3.1.2 <i>Mother's and infant's communicative-affective behaviours</i>	58
2.3.1.3 <i>Infant's emotional state and degree of engagement</i>	59
2.3.2 <i>Analysis of the mother's and infant's synchronisation</i>	59
2.3.2.1 <i>Self synchrony</i>	60
2.3.2.2 <i>Synchronisation with the musical beat</i>	61
2.3.2.3 <i>Synchronisation between mother and infant</i>	63
2.3.3 <i>Analysis of the tapped beat</i>	64
2.3.4 <i>Analysis of infant's emotional state and degree of engagement</i>	66
2.4 Overview of the chapter	66

Chapter 3 - Songs and their temporal structure in early interaction	69
3.1 The tempo of songs during interaction	69
3.1.1 <i>The identification of the mother's beat</i>	70
3.1.2 <i>The mothers' songs</i>	71
3.1.3 <i>The mothers' musical tempo</i>	73
3.1.4 <i>Mothers' most common tempos</i>	76
3.2 Temporal structure of music	76
3.2.1 <i>The song structure: meter organisation</i>	78
3.2.2 <i>The song structure: phrase duration and position in the song</i>	81
3.3 Discussion and conclusion regarding temporal structure of mothers' songs	85
3.4 Summary of the chapter	90
Chapter 4 - Mothers' and Infants' Physical and Communicative-Affective Behaviours in Interactions with Songs	93
4.1 How mother and infant participate in interactions with songs	93
4.1.1 <i>Types of cyclical behaviours produced by mothers and infants</i>	97
4.1.2 <i>Discussion and conclusions regarding infants' and mothers' physical behaviours</i>	101
4.2 Communicative-affective behaviours displayed by mothers and infants when mothers sing to their infants	106
4.2.1 <i>Mothers' and infants' communicative-affective behaviours in interactions with songs</i>	108
4.2.2 <i>Infants' emotional states and degree of engagement</i>	111
4.2.3 <i>Discussion and conclusions regarding infants' and mothers' communicative-affective behaviours</i>	113
4.3 How do mother and infant relate to the phrasing structure of the song?	115
4.3.1 <i>Mothers' and infants' level of activity in the phrases of the song</i>	116
4.3.2 <i>Discussion and conclusions regarding relationships between phrasing structure and level of activity</i>	119
4.4 Summary of the chapter	121
Chapter 5 - Synchronisation in musical interaction	125
5.1 Do mother and infant organise their behaviours in self synchrony?	125
5.1.1 <i>Analysis of mothers' and infants' self synchrony</i>	126
5.1.2 <i>Discussion and conclusions regarding self-synchrony</i>	128

5.2 Do mother and infant synchronise with the musical beat of songs?	130
5.2.1 Analysis of mothers' and infants' synchrony with the musical beat	133
5.2.2 Is mother/infant synchrony with the musical beat simply an artefact?	139
5.2.3 Mothers' and infants' synchrony with the beat across the phrases of the song	144
5.2.4 Mothers' and infants' synchrony with beat in relation to its position (and the metrical structure)	148
5.2.5 Which of the partners' behaviours are in synchrony with the musical beat?.....	153
5.2.6 Discussion and conclusions regarding mothers' and infants' synchrony with the beat	158
5.3 Do mother and infant display synchronisation with each other during interactions with songs?	169
5.3.1 Analysis of the mothers' and infants' behaviours in synchrony with each other in interaction with songs	171
5.3.2 Mothers' and infants' synchrony with each other as a function of each phrase of the song	174
5.3.3 Mothers' and infants' kind and category of synchronous behaviours	179
5.3.4 Discussion and conclusions regarding synchrony with each other	183
5.4 Summary of the chapter	187
Chapter 6 - Mother-infant interactions with taped music	192
6.1 Infants' sensitivity to taped music	192
6.2 Musical tempo of mother-infant interaction with taped music	193
6.2.1 The mother's musical tempo in interaction with taped music	194
6.2.2 Discussion and conclusion regarding the musical tempo of taped music..	198
6.3 How do mother and infant participate in an interaction with taped music?..	200
6.3.1 The partners' physical behaviours in interaction with taped music	201
6.3.1.1 The mother's and infant's type of cyclical behaviours	204
6.3.2 Communicative-affective behaviours mothers and infants display during taped music	207
6.3.3 Infants' emotional states and degree of engagement	211
6.3.4 Discussion and conclusions regarding mothers' and infants' participation in interaction with taped music	213
6.4 Mother and infant synchronisation in interaction with taped music	220

6.4.1 <i>Mother and infant self synchronisation</i>	220
6.4.2 <i>Mother and infant synchronisation with musical beat</i>	223
6.4.2.1 <i>The partners' synchrony with the musical beat</i>	229
6.4.2.2 <i>The partners' kind and category of behaviours in synchrony with the musical beat</i>	233
6.4.3 <i>Mothers' and infants' synchronisation with each other</i>	238
6.4.4 <i>Discussion and conclusions regarding mothers' and infants' synchronisation with self, the musical beat and the other partner</i>	247
6.5 <i>Summary of the chapter</i>	256
Chapter 7 – General conclusions and discussion	263
7.1 <i>Major findings</i>	265
7.1.1 <i>The function of musical tempo</i>	269
7.1.2 <i>The function of context and age</i>	270
7.1.3 <i>Taped music versus live songs</i>	271
7.2 <i>What drives the interaction in musical contexts</i>	272
7.3 <i>What drives the human sensitivity to music</i>	273
7.4 <i>Shortcomings of the study</i>	274
7.5 <i>Suggestions for follow-up experimental research</i>	275
Bibliography	277
Appendix	289

CHAPTER ONE

Temporal organisation in mother-infant interactions in musical contexts

Music permeates the life of all human cultures. Whether a foetus in the womb, a postnatal infant, a child or an adult, we cannot help but respond to the rhythms and temporal organisation that constitute our musical environment. It is thus no surprise that researchers in psychology have found music to be a fascinating topic of enquiry across the lifespan. Indeed, it is particularly the last decade that has witnessed a significant increase in studies of the role of music in human infancy. This body of research has covered a number of interesting aspects of music. However, hitherto little attention has been given to the nature of the songs that mothers actually sing to their infants nor, in particular, either to the temporal structure of such songs or to the special qualities of the musical interaction that mothers and infants jointly create. The research in this thesis therefore aims to explore the emergence of temporal structure in mother-infant musical interaction, focusing on mothers' songs and the use of taped music. In particular, the thesis will provide a detailed analysis of how the partners of a dyad relate to music.

In order to examine these issues, we first need to reflect on how rhythm and tempo emerge from music and how they are involved in human life. This chapter is therefore structured in two parts: the organisation of tempo in human life and the organisation of music in human life. Part 1 examines tempo in general and its implications for psychological theory, infant development and mother-infant interaction. Part 2 looks more directly at music from these same two perspectives: infant development and mother-infant interaction. The question is raised as to why mothers sing to their infants and followed by the intriguing question of whether mothers create a special quality of singing that one might call "songese", in just the way they later create the sing-song style of "motherese" to talk to their young infants. The interesting relationship between communication, emotion and music is examined. In a final section in part 2, I review Trevarthen's theory of Innate Musicality and discuss the pros and cons of such an approach. This first chapter ends by outlining of the aims of the thesis and the overall structure of the remaining chapters.

1.1 The organisation of tempo in human life

1.1.1 Tempo and Rhythm and their theoretical implications for psychology

Tempo is the speed at which beats of the music occur and this is commonly indicated by a metronome. A generally accepted definition of rhythm does not exist. However, in this thesis I adopt that of Fraisse (1982, p.150): "Rhythm is the ordered characteristic of succession", which we perceive. Fraisse suggests that we perceive rhythm through song, music, dance and poetry. Moreover, rhythm is perceived on the basis of prediction, making it possible to anticipate what follows. As Plato applied rhythm to body movements, so Fraisse maintains that all the rhythms we experience derive from human activity. Already in the 19th century, however, Mach (1865) and Vierordt (1868) proposed a relation between rhythm and body movement. And, as early as 1920, Dalcroze published his method of eurhythmics which aimed to develop a sense of rhythm through body movements.

The perception of rhythm is a crucial element of Fraisse's theory which is more thoroughly described in his book 'The Psychology of Time' (1964). Here, he extends his definition of rhythm explaining that "...rhythm is a special case where the unit of successive elements is better seen because it is always identically repeated. The organisation of successive elements into units of perception is, however, such a fundamental part of our experience that we no longer notice it. It is the basis of our perception of rhythm..." (p.72). Fraisse emphasises perception as the main characteristic of our experience of rhythm. Periodic recurrence can transform the pure perception of rhythm into a more complex experience, defined by a strong affective motive. In this way, the experience of rhythm has a social implication: the same stimuli produce the same responses in different individuals.

The perception of rhythm implies the perception of other salient characteristics: 1) cadence, 2) periodicity, 3) time, and 4) duration. Cadence is the most easily perceivable tempo based on the repetition of the same stimulus at a constant tempo. Periodicity is a crucial element of the perception of rhythm, characterised by regularity. In fact, periodicity makes it possible to perceive an unmodified rhythm despite the fact that the stimulus accelerates or decelerates. The perception of time is also relevant for the perception of rhythm and is based on the identification of a succession of units, i.e., order. Order is intrinsic to the stimulus itself and, in relation to rhythm, it is impossible to reproduce individual elements in any other order. In this respect, memory is believed to play an important role in the experience of order. Finally, duration, i.e., the perception of temporal interval, is also a salient characteristic of the perception of rhythm. When the duration of an interval is modified within a rhythmic group,

the apparent duration of the other intervals is also changed. Fraisse proposed that the temporal limit for the perception of a stimulus is between 1.5 and 2 seconds. If an interval lasts longer than this, perception of an organised succession of change fails to occur.

Fraisse (1964) explored the quality of perceived duration in the interval between stimuli onset and suggested three zones of interval between stimuli:

- 1) Short interval, less than 0.5s between stimuli onset. In this case, we only perceive the onset stimuli but not the interval.
- 2) Indifferent interval, from 0.5s to 1s between stimuli onset. In this case the stimuli onset and the perceived interval form a single unit.
- 3) Long interval, more than 1s between stimuli onset. In this case the perception of a gap is dominant, and the linking of onsets of stimuli becomes effortful.

The second of Fraisse's interval zones, the indifferent interval, is what is perceived to be neither too long nor too short, and corresponds to the natural perception of an interval. On the basis of his and others' similar findings, Fraisse (1964) suggested that there is a relationship between the indifferent zone and specific physiological processes. He claimed that "... walking, heartbeats, movements effected at a spontaneous tempo, and perceptions all follow on at intervals of about 0.7s which we consider to be the optimum interval for the functioning of the nervous centres because it is the most economical." (Fraisse, 1964, p.128). Therefore, around 0.7s is the central tendency for the most commonly perceived durations, with a range between 0.1s and 1.8s. In the thesis, I will examine these temporal constraints in detail in relation to mother-infant musical interaction.

However, the perception of time and duration are not only important for our perception of rhythm, they also constitute the basis of our experience of the world and how we process information. In fact, they affect the way we perceive events as fast rather than slow, or located before rather than after each other. Fraisse and other authors have identified 3 temporal processes we use to understand and process information from our everyday experience:

- 1) 'psychological present',
- 2) 'spontaneous tempo',
- 3) 'preferred tempo'.

"Psychological present" has been defined in several ways: 'psychological or perceived present' (Fraisse, 1964), 'sensitive present' (William James, 1891), 'mental present' (Pieron, 1923), and the 'actually present' (Koffka, 1935). The psychological present "...enables a

temporal sequence to be processed as a unit. It may be regarded as a non-verbal short-term memory possessing a high degree of structure and organisation" (Deutsch, 1975, in Parncutt 1994, p.450). According to Parncutt (1994) in the perception of language, the psychological present allows for different parts of a sentence or clause to be grouped together and understood as a whole (Fraisse, 1982; Wallin, 1901). The duration of the psychological present "...is dependent on the possibilities of organisation, everything which facilitates this - the attitude of the subject, grouping by proximity, structure, meaning - increases the richness of what constitutes our present" (Fraisse, 1964, p.92). Fraisse identifies the duration of the perception of succession, i.e., psychological present, as lasting about 5 seconds. He recognises the favourable interval for perception between stimuli as between 0.15s and 0.75s. This thereby limits the number of elements we perceive: 5 or 6 elements in a unit. However, other authors identified a slightly different duration of the psychological present. For instance, Michon (1978) suggested a psychological present ranging between 2s and 8s, whereas Fricke (1989) proposed a period between 7s and 15s. According to Michon (1978) the variety of durations are due to the fact that the psychological present is extremely flexible and we thus cannot apply constraints. This thesis will analyse the second-by-second characteristics of mother-infant interaction in musical contexts.

"Spontaneous tempo" (Fraisse, 1964), has been referred to by Stern (1900) as 'psychic tempo', Frischeisen-Kohler (1933) called it 'personal tempo' and Mishima (1951-52) 'mental tempo'. This tempo is characteristic of voluntary activity and it can be measured by the natural speed of tapping. The most representative duration of the spontaneous tempo is in the region of 0.6s, with inter-individual variability from 0.38s and 0.88s. Similarly, when subjects were asked to tap the beat of the rhythm played, Parncutt (1994) found that their pulse response was around 0.6s-0.7s, irrespective of the rhythm beat rate. Finally, "preferred tempo" "...corresponds to the speed of a succession of sounds or of lights that appear to be most natural" (Fraisse, 1982, p.153). In other words, it is neither too slow nor too fast. And again, the most common duration has been found to be in the region of 0.6s. The picture becomes striking if personal tempo, preferred tempo, the rhythm of the heart beat, and the pace of walking are compared: they actually show a narrow range of interval between 0.6s and 0.7s. All these similarities led Fraisse to hypothesise that one of these rhythms might work as pacemaker for the other rhythms, but no evidence has been found in support of this. In this thesis, I investigate whether evidence that mothers and infants constantly adapt their interactional tempos to such narrow ranges of temporal organisation.

Although rhythm and tempo have been treated as metaphysical concepts, their impact on human life is vast and profound. Rhythm (as it relates to temporal order) is a fundamental phenomenon of human life which allows one both to discriminate and to order events that otherwise would be perceived as a chaotic stream of unrelated information. The perception of time and duration contributes to the organisation and structuring of our experience of the world. The existence of preferential rhythms in perceptual input and in the production of actions implies that we need an internal temporal referent which allows us to perceive the pace of events, to link information together and to regulate our participation in the external world. In the next section I examine how infants experience rhythm from early in life.

1.1.2 Temporal organisation and its psychological implications for infant development

At birth the infant enters into a temporally organised world where his own behaviour is also characterised by temporal patterns. Berges (1982) noted a relation between rhythms and human biological life and claimed that rhythms change during early development and become integrated into the central nervous system. According to Wolff (1967), the infant's endogenous rhythms control his adaptation and early social interaction. Wolff compared the rhythmic crying and sucking behaviour in newborns with stereotypic mannerisms like rocking and kicking in older normal children as well as deprived children and children with abnormal development. He found that early biological rhythms prepare for the acquisition of new motor patterns or postures. Also, Thelen (1981) observed that the infant's rhythmic behaviours are very important in early motor development. She noted that in the first year of life, infants show a great variety of stereotypic rhythmic behaviours with their head, arms and legs. For instance, from birth infants kick their legs when lying on their back or stomach, and this activity becomes more frequent by the time they reach 6 months of age. Comparing the kinematics of kicking and stepping, Thelen observed that the time and space patterns of these actions are basically the same. Moreover, she demonstrated that flexion, extension and pause of leg kicking are expressions of the central motor programme, which are precursors of later walking activity (Thelen, 1981; Thelen et al., 1981).

A social implication of the infant's biological rhythms comes from Stratton (1982) who suggests that rhythmical social interactions are biologically based and reflect the temporal patterns typical of biological systems, such as breathing and brain activity, crying and sucking, sleep and wake cycles, and so forth. The benefit of biological rhythms in the infant's adaptation is explained by Sollberger (1965) and Winfree (1980) who emphasised

“...the biological advantages of control systems which oscillate around a mean rather than trying to maintain a fixed level. In particular the existence of a rhythm makes it easier for the organism to capitalise on regular environmental occurrences which have comparable periodicities. Endogenous pacemakers would seem to offer considerable advantages in the control of repetitive functions such as respiration until the immature organism has acquired sufficient learning experiences and maturation of the neural substrate to take over more sophisticated and adaptive control” (Stratton, 1982, p.119).

Another theorist to examine infants' endogenous rhythms was Ashton (1976) who argued that such rhythms become less dominant as the infant learns to integrate them with rhythms from the environment. Provasi (1988) tested this hypothesis by comparing the activity of newborns and 2-month-old infants. Using a non-nutritive sucking paradigm, he tried to modify the infant's temporal activity by introducing a pleasant auditory stimulus, e.g., a recording of the mother's voice, the heart beat of the intrauterine environment, or music. First of all Provasi measured the natural duration of the pauses between spontaneous sucking activity. Then, in the reinforcement phase, he related a pleasant auditory stimulus to a shorter or longer duration of the pause. For example, a sucking burst generated the auditory stimulus only if it followed an interburst interval less than the 30th percentile of the interval baseline. Although the infants did not learn this procedure immediately, after a few trials the older infants learned easily to decrease their pauses but found it more difficult to prolong them between bursts of sucking, whereas newborns did not learn to lengthen their pauses.

A different experiment on the modification of motor co-ordination patterns in 3-month-old infants was proposed by Rovee-Collier (1993) and Thelen (1994). They tied the infant's leg to a mobile, so that spontaneous leg kicking made the mobile jiggle. After a few minutes infants learned that the faster and more vigorously they kicked, the faster and noisier the mobile would be. Moreover, infants demonstrated memory of their motor activity over several weeks or longer if the same context re-occurred. In sum, these studies show that infants are capable of modifying the temporal organisation of endogenous rhythms in response to an appropriate environmental stimulus. According to Pouthas (1996), infants' ability to process temporal information, as well as organise their behaviours temporally, is fundamental for the development of their motor, cognitive, perceptual abilities and emotional state. Also, she suggests that infants' early temporal regulation is crucial for future, more complex temporal learning (Pouthas, 1990). However, to be able to process and organise temporal information, the infant needs to detect even small differences in time, and we will

see in the chapters of this thesis how important such tiny temporal variations are during mother-infant musical interaction.

As infants develop, they increasingly integrate their actions with stimuli from their surroundings. An important role in this integration is provided by the perception of both rhythmic structure and a more general structure (Lewkowicz, 2000). Rhythmic structure is also relevant from the point of view of production, because our movements are normally rhythmically organised. Several authors have found that even young infants have the ability to discriminate rhythms. For instance, Demany and colleagues (1977) noted that from two months of age infants are able to discriminate different acoustic sequences, and Mendelson (1986) observed that 4-month-old infants can discriminate visual rhythmic sequences. Although these studies explored rhythmical discrimination in infants, they focused only on simple rhythmical organisation, neglecting the more complex hierarchical structure of rhythm which we will look at in this thesis. Morrongiello (1984) investigated the response of relatively complex auditory rhythmic patterns in 6- and 12-month-old infants. Two different rhythmical patterns were presented. They differed in absolute terms (the inter-element intervals changed) or in relative terms (the inter-element intervals were played in a new combination). Both groups of infants could discriminate the difference when it was in absolute terms, but only 12-month-old infants could detect a relative difference. In another study, Pickens and Bahrick (1995) found that infants of 7 months of age could discriminate relative, complex auditory-visual rhythmic sequences. In a more recent study by Bahrick and Lickliter (2000), which used the same rhythmic stimuli as the Pickens and Bahrick (1995) research, it emerged that 5-month-old infants also display the same discrimination abilities. We can therefore conclude that by 5 months of age, infants are able to discriminate rhythmic patterns, but their responses depend on the complexity of the pattern and whether or not the stimulus is unimodal or bimodal.

Another interesting piece of research comes from Baruch and Drake (1997) who tested two theoretical positions with respect to temporal discrimination in infants: 1) suggested by Fraisse (1957, 1967) and by Drake and Botte (1993), that the auditory system has a greater temporal sensitivity in an intermediate tempo range which occurs between 300 and 800ms IOI (interonset interval), and that infants and adults have the same optimal zone; and 2) supported by Jones (1982) and by Jones and Boltz (1989), that the optimal zone (called 'reference period' by the authors) slows with age, with infants being more sensitive to faster tempos than adults. Baruch and Drake (1997) tested whether, like adults, infants can

discriminate isochronous sequences which vary slightly in tempo. Using a habituation paradigm associating visual fixation time with auditory sequences, the authors tested 2- and 4-month-old infants to see whether they could distinguish sequences of 100ms, 300ms, 600ms and 1500ms IOI in the habituation phase, from faster sequences in the test phase. Both groups of infants were able to discriminate between the two isochronous sequences which differed only slightly in tempo. The authors suggest that infants are able to integrate sequential events in a group and extract a constant from the series (in this case, the duration of interval between events). Therefore, early in infancy there already exists a mechanism for extracting tempo. However, it is interesting to note that infants had more difficulty with 1500ms tempo, probably because at this very slow tempo they have problems incorporating events as part of a single perceived group. It could also be due to memory limitations. Similarly to adults, both groups of infants showed that they could discriminate tempo mostly at 600ms, which represents an intermediate tempo. Baruch and Drake (1997) repeated the same study with 4-month-olds, testing the same isochronous sequences but at a faster rate and obtained the same results. This indicates that 600ms is a robust and relatively tight optimal zone. In another study, Drake (1998) found that 2-month and 4-month-old infants were more likely to notice and react when the speed changed to a pulse every 300ms as well as at 600ms, but not at slower rates. Therefore, on the basis of Jones' theory, Drake argued that infants are more sensitive to faster tempos and that the preferred tempo slows down with age. To test this hypothesis, Drake played two different tempos to a group of volunteers between 4 and 20 years of age and asked them to identify the faster one. Children were able to identify accurately at around 400ms interval, whereas in adults this capacity was at about 600ms interval.

Since the two hypothesis are not strictly mutually exclusive, there is a sense in which the empirical results can be taken as support for both positions. They corroborate Fraisse's (1957) view that there is a link between optimal zone and preference for intermediate tempi around a temporal region of 600ms for both adults and infants. But they also support Jones' (1982) hypothesis that children discriminate tempo more accurately at 400ms and adults at 600ms. This suggests that children are more sensitive to fast tempos compared to adults, and that the optimal zone slows with age. But what about infants? Are they already more sensitive to faster tempos rather than slow ones, as are young children?

Fine temporal discrimination in infants is crucial in their daily life because it calls on their ability to perceive and co-ordinate information from different modalities and respond

appropriately to them. The relatively few studies on intersensory temporal ability in infants are quite recent, although in the past several researchers (e.g., Birch & Lefford, 1963, 1967; Piaget, 1952; Werner, 1973) recognised the crucial role of intersensory integration for the development of infants' perception and behaviour. In her book on 'Principles of Perceptual Learning and Development' E.J. Gibson (1969) discussed the relevance of perception of multimodal information for understanding the development of perception and learning in infants. Several authors followed Gibson's theory suggesting that intersensory integration offers the basis for the development of cognition, action and perception (Lewkowicz, 2000). For instance, Edelman (1992) and Thelen and Smith (1994) proposed that intersensory relations provide the foundation for the development of new, essential behavioural abilities which then become crucial for the development of higher cognitive and perceptual operations. Several studies have demonstrated how intersensory integration is already present at an early age in infancy, concentrating mainly on intersensory integration of auditory and visual stimuli. For instance, Spelke (1979) and Spelke et al. (1983) used an intersensory paired-preference paradigm. They showed a group of 4-month-old infants two films simultaneously of an object moving up and down in a rhythmic sequence, one on the left and the other on the right side of the midline. Occasionally there were abrupt changes in the direction of the object and a single sound track was played of an abrupt noise. Spelke and colleagues found that infants looked longer at the film whose abrupt change of object direction was synchronised with the abrupt change of the sound track. Sensitivity to synchronisation will, we shall see, be a central focus of this thesis. In other studies, Morrongiello and colleagues (1998) observed that newborns relate objects and sounds on the basis of collocation and synchrony combined together. By 3 weeks of age, infants associate auditory and visual stimuli on the basis of intensity (Lewkowicz & Turkewicz, 1980). In contrast, 3- to 4-month-old infants match objects and sounds on the basis of temporal synchrony and temporal microstructure (Bahrick, 1983, 1988; Lewkowicz, 1992). The objects or events need to occur dynamically because until the age of 6 months infants have difficulty discriminating spatially static visual information. Also, Kuhl and Meltzoff (1982) demonstrated that 4-month-old infants link together auditory and visual properties of a syllable. Likewise, Rosenblum et al. (1997) showed that 5-month-old infants display the McGurk effect which involves the integration of auditory and visual information about a syllable.

These studies show how, from an early age, infants are sensitive to temporal synchrony in audio-visual and tactile-visual relations. Although there has been a general inclination to

attribute innate origins to the integration of sensory information because of its early appearance in infant life, this hypothesis has not obtained strong support. Also, the fact that some intersensory relations are not available until later indicates that some kind of stimuli or information are processed only after experience (Humphrey & Tees, 1980; Lewkowicz, 1985; Spelke, 1994). However, infants are sensitive to multimodal temporal structures and they also respond appropriately to them in relation to their stage of development. For instance, infants not only are sensitive to different temporal variations, but they also are able to perform anticipatory responses on the basis of temporal information (Berg & Berg, 1979; Clifton, 1974; Donohue & Berg, 1991). Infants' anticipatory movements have been demonstrated by several researchers who noted that infants can make anticipatory hand movements in relation to the future position of an object as it moves in space (von Hofsten, 1983). Also, infants anticipate the spatial position of an object by anticipatory eye movements (Canfield & Haith, 1991). Moreover, infants' ability to relate different sensory information into a unified temporal unit allows them to co-ordinate and organise their actions in a temporally significant way (Stern et al., 1977). As we shall discover in later chapters of this thesis, this becomes extremely relevant in interaction with their caregivers. In fact, Lester et al. (1985) noted that the partners interlock in specific temporal patterns. As stressed above, infants' temporally-based perceptual and behavioural abilities are extremely important for their future cognitive development. Some evidence in this respect has been provided by Dougherty and Haith (1997) who found a relation between 3.5-month-old infants' visual reaction time/visual anticipation and IQ score at 46 months of age, measured on the Wechsler Preschool and Primary Scale of Intelligence - Revised.

Therefore, even young infants are sensitive and responsive to temporally-based intersensory information. This is important because, in everyday life, infants are surrounded by temporal auditory, visual, tactile, kinaesthetic and vestibular stimuli. A privileged expression of these modalities is found during interaction with adults when mothers play and talk or sing with their infants. In this context, infants' ability to integrate and match such information is crucial for prompting and supporting their interaction with caregivers, allowing them to interlock with emotional attunement. In the next section, I discuss the implications of multimodal temporal information in mother-infant interaction.

1.1.3 Temporal organisation and its psychological implications for mother-infant interaction

Rhythms occurring during social interaction provide a temporal structure for the infant who creates expectancies and organises emotional and cognitive experiences (Lewis & Goldberg, 1969; Stern et al., 1977). In the first weeks of the infant's life, interaction is dominated by biological rhythms. The temporal patterns involve: crying, sucking, circadian rhythms, brain activity, heart beat and breathing (Stratton, 1982). All these biological rhythms are control systems. They are not fixed but oscillate around a mean, allowing the infant to capitalise on regular external events that have the same periodicities (Sollberger, 1965). Caregivers also benefit from this regular oscillatory system because such regularities make infants predictable, facilitating the flow of the interaction (Lester et al., 1985). Early on, when dominated by endogenous rhythms, infants participate in the interaction with short cycles of attention and non-attention. During the non-attention cycles, which indicate disengagement, infants appear to take time to assimilate the information acquired during the attentional phase. In this way, they seem to maintain a homeostatic state, i.e., a self-regulatory mechanism, for maintaining regular heart beat, respiration and temperature (Brazelton et al., 1974). Stern (1985) also suggested that looking-away cycles might serve infants as a regulatory mechanism for arousal. In numerous parts of the thesis, I will examine whether and how mothers subtly adapt their musical interaction with their infants to maintain a homeostatic state.

Another pattern of temporal organisation observed during early interactions occurs at feeding time. Wolff (1966) noted that when drinking from the bottle, infants organise their activity in burst-pause patterns. Kaye (1977) demonstrated that these burst-pause sucking patterns are integrated into a more general temporal organisation of interaction with the mother. In fact, mothers appear to be sensitive to these patterns and synchronise with them. During the burst cycle, mothers are silent and motionless, whereas during the pause cycle they move, talk to their infants and rock them. So, it appears that this early social interaction is shaped by turn-taking. However, in the first weeks of the infant's life, both partners are likely to overlap and be asymmetric in their exchange. It is only after a few weeks that their interaction becomes more harmonious and the partners take symmetric turns (Kaye & Fogel, 1980; Longhi, 1992). It is worth noting that turn-taking, and in general the cyclical social exchange between mothers and infants, are considered important for learning rudimentary symbolic functions, for the development of language and for acquiring communicative roles (Kaye, 1977; Sander, 1969; Tronick, Als & Adamson, 1979).

Infants' vocalisations are characterised by duration, intensity, frequency and temporal organisation of the sounds (Papousek & Papousek, 1981). Analysing these rhythmic vocalisations in young infants, Fridman (1980) claimed that they are 'proto-rhythms', constituting 'natural rhythmic schemes' already present in early vocalisations and which underlie the rhythms of adult speech and classical music. Stern, Beebe, Jaffe and Bennet (1977) emphasised the importance of timing in communication, and proposed that temporal organisation could be the fundamental principle underlying early social interaction. "With respect to temporal organisation in the kinesic realm, one of the most salient findings has been that in the period of 3 to 4 months, infant and mother both literally live in a 'split-second world' where the average behaviours of each last approximately 1/3 second...this is a world of 'microreactivity' in which each is extraordinarily sensitive to the movements of the other, each potentially 'responding' to the other within less than 1/2 second" (Beebe & Stern, 1977; in Beebe et al., 1979, p.24). Therefore, both partners soon become sensitive to the other's temporal behaviours and responses (Beebe et al., 1985; Beebe & Lachmann, 1988). Mothers and infants show attunement in their dyadic interactions where each partner tracks the duration of the movements, as well as the facial, vocal and emotional expressions of the other (Beebe et al., 1992). In this thesis I will examine whether such subtle dyadic interactional adjustments also characterise musical interaction between mother and infant.

Early social interaction thus appears to be a finely structured and organised context in which the flow of communication is ensured by the partners' ability to respond appropriately by taking turns with each other. But how are these temporally organised patterns structured in the interaction, especially when music is involved? During the interaction the mother's participation is particularly relevant, because she in fact defines and adjusts the structure of the interaction according to the infant's state. Several authors have noted the central role of mothers' rhythms in the interaction and regulation of the infant's rhythm (see for example Brazelton et al., 1974; Papousek & Papousek, 1987; Stern, 1974). According to Korner (1979), the smooth flowing of the interaction depends upon the adult's ability to tune in with the infant's behaviours, modifying appropriately their responses, and ensuring the achievement of the infant's homeostasis.

Maternal micro-rhythms captured the attention of Papousek and Papousek (1981) who observed that mothers have a rich set of rhythmical patterns which they use in response to the infant's state, so as to modulate his behaviours and emotions in the interaction. Sullivan and Horowitz (1983) noted that the mother's "regular synchronisation of vocal and kinetic

patterns provides the infant with multimodal sensory information including tactile (stroking, patting, tapping, poking), kinaesthetic (moving infant's hands and/or feet), and visual information (head nodding, head shaking)" (in Deliege & Sloboda, 1996, p.100). Papousek (1996) observed a relation between the mother's behavioural periodicities and her vocal expressions. For instance, the mother's head nodding synchronises with the prosodic stress and tempo of her vocal utterances. Head shaking seems to be synchronised with utterances of disapproval (at least in German), the tempo of rocking and stroking is similar to maternal singing, and the tapping and tickling tempo synchronises with the tempo of the mother's linguistic output, i.e., syllables per seconds.

An interesting study on maternal patterned behaviours comes from Koester et al. (1989) who explored the nature of mothers' micro-rhythms in interaction with their 3-month-old infants. These authors observed and videotaped, in the laboratory, 17 mother-infant dyads during face-to-face interaction. The infants sat on a rocking chair. The researchers then measured the occurrence and mean duration of the mothers' tactile (stroking, patting, tickling), kinaesthetic (moving infant's limbs), vestibular (rocking), and visual stimuli (head nodding, shaking, and tongue playing). They also assessed the infant's gaze direction: to the mother, to the mirror (placed behind the dyad), and to 'other' (self, environment or unclear). The analysis of maternal rhythmical patterns showed that head nodding occurred at a slower tempo in comparison with the tactile and vestibular stimuli, which were faster for playful proposes. Moreover, the mothers tended to make faster rhythmical behaviours when the infants looked away in comparison with when the infant was looking at them. The overall mean duration of mothers' rhythmical activity was significantly longer when the infant looked away, whereas the overall mean durations per 'beat' (cycle) were significantly longer when the infant looked at the mother. This means that, when they have the infant's attention, mothers perform slower rhythmical patterns but in shorter bursts, whereas they stimulate the infant for longer periods and faster when the infant looks away. The authors also carried out more detailed analyses of one dyad, which revealed that the mother's facial stimuli are performed when the infant looks at her and, as the infant looks away, she interrupts the face stimuli, e.g., head nodding, and starts to present tactile stimuli. In other words, the tempo of the patterns changes: slower with the infant's attention, faster when the infant is distracted. A major aim of this thesis is to examine whether such patterns hold not only for linguistic interactions but also for musical ones.

Koester and colleagues found that mother-infant interaction is very rich. Mothers perform a great variety of temporally organised behaviours even when their infants are only 3 months of age. Moreover, they observed that maternal activity does not depend solely on the infant's state, but is also governed by physical principles. They found that the variety of tempos and maternal behaviours demonstrates the dynamic state of the interaction and the idiosyncrasy of the mothers. From this study they concluded that, not only do infants come into the world competent and well equipped, but also their parents are well prepared to interact with them. In fact, parents have a repertoire of behaviours, of which they are mostly unaware, to help their infants fit into the social and physical world (Papousek & Papousek, 1977, 1987). Also, this parental behaviour ensures the infant's effective learning through simplicity and repetition (Fogel, 1977; Messer, 1980; Turkewitz & McGuire, 1978). Such considerations, as we shall see throughout the thesis, turn out to be very relevant to musical interaction.

Interestingly, Stern (1977) also found that repetition plays an important role in mother-infant interaction. In fact, he postulated that repetitive runs are behaviours which occur during the sequence of other behaviours within an episode of inter-individual engagement. These repetitive behaviours are both verbal and non-verbal; they are multimodal. A crucial characteristic of the runs is that they are usually followed by a 're-representation' of the stimulus, but slightly changed. This idea of repetitive runs led Stern et al. (1977) to suggest that mothers establish a beat or pulse during an 'episode of maintained engagement'. Therefore, during an episode of engagement, through verbal and non-verbal behaviours mothers establish a regular tempo which creates expectancies in the infants, and in doing so, mothers introduce some small temporal variations to keep their infant's attention. It is the partners' ability to anticipate and estimate accurately intervals of time which ensures the smooth progress of the interaction from one event to the next. In the thesis I will ask whether this holds equally in mother-infant interaction with both songs and taped music.

Beebe et al. (1982) tested Stern's hypothesis, by exploring the effect of the mother swinging the infant's hand with her own hand on a horizontal level. When the mother started the hand game, they observed a dramatic effect on the infant's engagement level. In fact, the infant changed orientation and looked at the mother, and his facial expression changed from sober to increasingly positive. A significant difference in the infant's level of engagement was noted in relation to the rhythmic maternal intervention. Beebe et al. (1982) proposed a hierarchy in the relationship between rhythmic games and infant's level of engagement. In the presence of regular rhythmic games, the infant's engagement is highly positive. This is

followed by an intermediate level in which the infant displays slightly positive levels of engagement. When the rhythmic game stops, the infant shows the lowest level of engagement. Such a relation between rhythmic patterns and positive infant affect was already hypothesised by Brazelton et al. (1974) and Stern et al. (1977). Another implication of this relationship is that the infant's level of engagement decreases if the mother is irregular in her tempo and movements and if she does not maintain repetition. This is because the infant is unable to predict the maternal behaviour. However, Beebe et al. (1982) pointed out that, to affect the infant's engagement, the mother's repetition of rhythmic games must be accompanied by kinesic variation in mean tempo and cycles. In fact, as mentioned above with respect to other studies, when maternal cycles become very fast, the infant's engagement actually decreases, supporting Tronick et al.'s (1979) hypothesis that the slower the mother's tempo, the higher the level of the infant's engagement. A minimal variance in the mother's mean cycles also affects the infant's engagement, and this is consistent with Stern et al.'s (1977) notion that to hold the infant's attention, the mother's repetition and rhythmicity must be characterised by variability. Therefore, rhythmicity alone is not enough to influence the infant's state. Rather, it is the combination of tempo and degree of variance that affects the infant's engagement level. In this light, the mother appears to be an external pacemaker who "...provides the infant with the exactly appropriate range of high frequency rhythms with which to entrain his own endogenous microrhythms" (Beebe & Gerstman, 1980, in Davis, 1982, p.93). More recently, Gratier and Devouche (2000) explored the beat/pulse established by mothers with their 8-10 week-old infants. They carried out detailed analyses of 5 mothers' and their infants' vocalisations and behaviours, and noted that all dyads exhibited extraordinary timing regularities. Irregularities were observed too, and they involved new pulses. These authors noted that a great amount of verbal and non-verbal behaviours clustered around an interval of 800ms.

In sum, the mother typically produces a large variety of temporally co-ordinated cyclical patterns which involve different modalities. Although her performance is characterised by variation to ensure a homeostatic state in the infant, she establishes a regular 'beat' around which the interaction is structured and organised. However, as mentioned above, it remains unclear which kind of beat the mother establishes in interaction with her infant because it involves the convergence of different temporal events. One hypothesis is that the mother's beat might correspond to the neutral zone, i.e. around 700ms, because it represents a time where naturally occurring psychological processes occur. However, a better way to identify the mother's beat is, as we shall see later in the thesis, to use a tool which has a naturally

embedded beat, i.e., music. But first we will look at the important issue of synchrony in mother-infant interaction.

1.1.4 Synchrony in mother-infant interaction

An important aspect of the temporal organisation of mother-infant interaction is synchrony, which occurs when two or more behaviours occur simultaneously. Fraisse (1982) suggests that synchronisation presupposes anticipation, which is possible when there is periodicity of signals. Condon (1979) claimed that the principle of individual and interactional behaviour is synchrony, which he tried to understand by studying the micro-organisation of the interaction. He emphasised that the participants in the interaction organise their verbal and non-verbal behaviours temporally, as in a dance. In fact, "...such integration (or organisation) is manifested in the synchronised timing or changing together of the aspects of behaviour with each other, including both speech and body motion" (Condon, 1979, in Bullowa, p.131). According to Condon, prior to synchrony with another person comes self synchrony, which is the simultaneous activity of different body parts. Although the parts of the body move in different directions and with different tempos, they keep an overall order which forms a single unit of behaviour. It is the central nervous system that contributes to the orderly organisation of behaviours. Therefore, human behaviours are integrated in their occurrence and are hierarchically organised across time. Condon analysed in micro detail the human behaviours occurring in an interaction, applying the frame-by-frame technique. Thanks to this approach, Condon showed that a listener moves in synchrony with the words of the speaker. He called this phenomenon, 'interactional synchrony', and the internal process that allows the person to synchronise, 'responsive entrainment'. In fact, he found that the listener moves in patterns of behaviours parallel to the speaker's verbal patterns within a latency of 50ms. Such an accurate ability of the listener to synchronise with the speaker's speech led Condon (1977) to suggest the existence of "...a primary, short-latency entrainment phase in the human process" (in Bullowa, 1979, p.138), a process similar to self-synchrony. Whether such tight synchrony exists also in musical interaction is a question addressed in this thesis.

In 1974, Condon and Sander also demonstrated that newborns (1 to 4 days old and even only 20 minutes old) are able to entrain within 50ms with either the live human voice or a tape recorder. Moreover, the infant listeners were able to separate the linguistic structure of sound into segmental units, such that they moved their bodies in parallel to the duration of these units and changed to a new set of behaviours when the sound changed. Condon proposed

that the short-latency entrainment phase might be a pre-cognitive response. He also analysed the synchronisation and entrainment of infants with learning difficulties, such as autism, aphasia, cerebral palsy etc., and found that in comparison with normal infants, those infants responded too late (1 second or more) and too intensely to the sounds, a sort of multiple entrainment.

Although Condon's work is valuable for its accurate microanalytic approach and precise definition of human interaction, his methodology is rather subjective and failed to be replicated. However, other researchers (Beebe et al., 1982; Brazelton et al., 1974; Tronick, et al., 1977) also considered the harmonious interaction between mother and infant to be synchronous. This synchronic interaction has been referred to in different ways: "attunement" (Field, 1985; Stern, 1977); "mutual regulation" (Tronick & Gianino, 1985); and "rhythmic structure" (Lester, Hoffman, & Brazelton, 1985).

Synchrony is so important that when it is missing it can give rise to atypical development. Some authors (see Bakeman & Brown, 1980; Field, 1979) have explored synchronic interaction with pre-term infants, and shown them to be more difficult social partners than full-term infants. It turns out that caregivers of pre-terms need to invest more time and energy to obtain attention. Difficulties with synchronous interactions also occur when mothers are depressed (see Cohn et al., 1986; Field et al., 1988). During interaction, depressed mothers exhibit fewer contingent responses, flat affect, and their infants are less active and attentive, and more difficult to please (Field et al., 1984; Field et al., 1985). Observers speculated that depressed mothers are rarely synchronous in sharing the same state with their infants. If this were true, it would imply that the normal harmonious interaction suggested by Beebe et al. (1982) and Brazelton et al. (1974) is less likely to occur when mothers are depressed. Cohn et al. (1986) also found that mutual attention and contingent responsivity are quite poor in interactions between depressed mothers and their infants, suggesting that sharing behavioural states is more difficult. Also, Field (1987) argued that synchrony of interactive behaviour between infants and depressed mothers was highly unlikely. In fact, she suggests that in normal interactions, mothers constantly monitor their infants' states to ensure the right level of stimulation and arousal, allowing mother and infant to synchronise their attentive and affective behaviours. In contrast, depressed mothers are emotionally unavailable or non responsive during the interaction. Their infants experience disorganisation, and consequently their affective and attentive behaviours become asynchronous. Therefore temporal co-ordination and, in particular, synchrony are

crucial factors for the smooth flow of communication within the interaction. It is the organisation and micro-timing of both partners' behaviours that ensure the harmonious flow of the interaction. On the other hand, when the mother is not able to present contingent responses and her stimulation is occasional and disorganised, the infant loses interest and the interaction becomes asymmetric and asynchronous.

* * *

To summarise, in this first part of the chapter I examined the relevance of rhythm in life, in particular how the perception of rhythm helps to organise our experience of the world. Several studies concur that it is with a periodicity of around 600ms that most of the physiological and psychological processes occur. The experience and perception of rhythms occur early in human life. In fact, young infants not only perceive temporally organised stimuli from different modalities that they integrate, but they also produce rhythms that stem from physiological processes. These abilities allow them to order surrounding events and create expectations so as to organise their behaviours accordingly. Also, temporal perception and discrimination play a fundamental role in interactions with mothers where infants are exposed to visual, auditory, kinaesthetic, vestibular and tactile stimuli. In fact, mothers perform a wide variety of temporally organised behaviours through which they establish a 'beat'. The 'beat' of the interaction is not rigid. Rather, it is characterised by variability in order to maintain the homeostasis of the infant's state.

Given that beat is naturally embedded in music, which beat do mothers establish when they provide music in their interaction with the infant? We have seen that through the integration of intersensory temporal information infants are able to anticipate beat and organise their participation accordingly. Does the infant understand the temporal structure of an interaction when the mother uses music and songs? And is the infant able to attune with the mother during interactions which are temporally organised by music?

In order to understand how music is involved in the temporal organisation of mother-infant interaction, we need to explore the relation between rhythm and music as well as the importance of music in human life, especially in early interaction when caregivers sing to their infants. In the second part of this chapter we explore the implications of music and musical rhythms in human life, with particular attention to early social interaction. I particularly focus on: a) the emergence of rhythm from music in the form of beat, meter and

tempo, how these temporal elements shape music into a hierarchical structure, and how adults respond to rhythm in music; b) before birth, whether foetuses perceive musical stimuli, and after birth, how infants show fine auditory perception of musical stimuli; c) whether mothers use a special singing style (infant-directed singing or "songese") just as they use "motherese" (infant-directed speech); d) why caregivers sing to their infants, and in particular the tight relation between music and emotion; e) Trevarthen's (2000) theory of Innate Musicality; and, finally, f) Dissanayake's (2000) suggestion that the origins of music are to be found in the temporal patterns of early mother-infant interaction.

1.2 Music in human life

Little research has hitherto been devoted to understanding the nature of rhythmic behaviours in music. However, researchers in music psychology have proposed three theories to explain human interaction with musical rhythms: 1) instinctive, 2) physiological, and 3) motor. The instinctive theory was mainly promoted by Seashore (1938) who argued that 'rhythmic capacity' is inherited and not learned. However, this position has been refuted on the basis of studies demonstrating that training can improve rhythmic abilities (e.g., Coffman, 1949; Nielson, 1930). Of course, this only refutes the hypothesis if rhythmic capacity turned out to be both inherited and fixed. Dalcroze (1921) was a strong supporter of the physiological theory, which asserts that physiological processes underlie rhythmic responses to music. In particular the rate of heart beat is the basis for the tempo and rhythm of music. Although this theory has often been entertained, there is currently no evidence to support it.

More accepted is the motor theory based on the assumption that rhythm depends upon the activity of voluntary muscles. Mursell (1937) observes that neuromuscular activity is strongly related to the brain, and together with the central nervous system and the brain, music serves to control voluntary movements. By contrast, Lundin (1967) considers that rhythmic behaviours involve both a perceptual and behavioural response. More accepted is the compromise learning theory by Lundin (1967) which stresses the importance of learning and links together perception and motor response to musical rhythms. He suggests that: "...perception of rhythm requires observation of rhythmic stimuli and may or may not involve overt behaviours. It involves both perceptual organisation of rhythmic stimuli and discrimination among stimuli" (Lundin, 1967, pp.106-113). Lundin continues by arguing that learning is the essential feature for organising and discriminating rhythmic stimuli.

More recently, Gabrielsson (1982, pp.159-163) proposed a model of music rhythms: “..musical rhythm involves musical performance, which produces sound sequences, which in turn may elicit psychological and physiological responses in the listeners”. According to Gabrielsson (1982), listeners present three different kinds of responses: 1) experiential, which involves perceptual, cognitive and emotional processes; 2) behavioural, which manifests itself in output and actions such as tapping the beat with one’s foot, swaying of the body, or dancing; and 3) physiological, which is an internal response and implies changes in breathing, heart beat, or muscular tension. So, in this perspective, rhythm is by nature the dynamic force and energiser of music, and it is on rhythm that our experience of music depends.

Several rather unsuccessful attempts have been made to provide a conventional definition of music (Cross, 1985; Nattiez, 1990). However, it is commonly agreed that music is a unique phenomenon present in the everyday life of cultures and communities, and that it is performed in different forms and for different purposes. Although recently music might have become a more aesthetic expression, especially in Western culture, its roots are functional. As Gaston (1968) pointed out, one of the main functions of music is to communicate nonverbally what cannot be conveyed verbally. And this, according to Sloboda (1985), is due to the biological evolution of human mental processes, which have brought together the development of both language and music. However, researchers who study the development of musical behaviours observed that from an early age, people respond differently to musical sounds versus other kinds of sound (Dowling, 1984; Fridman, 1980; Moog, 1976). Sloboda (1985) suggested that metre and pulse are essential attributes of music because they provide a ‘time reference’. Moreover, pitch and time reference are the necessary features of music that allow people to co-ordinate their activity so as to make the musical experience a social event. Sloboda’s position is interesting. In fact, we will suggest in this thesis that in order to experience music, pitch, timbre and loudness need to be ordered and temporally organised. The temporal structure with cadence and periodicity is typical of music, creating predictability and expectation in the listener. Rhythm is not only present in several aspects of daily life, most importantly it is naturally embedded within music. In fact, as Gaston (1968, p.17) stated “ Rhythm is the organiser and the energiser. Without rhythm, there would no be music, whereas there is much music that has neither melody nor harmony”. So, rhythm’s primary function seems to be to provide order (Radocy & Boyle, 1997).

The attributes of musical rhythms are numerous, but for the purpose of this thesis we concentrate only on: beats, meter, and tempo. The beat or pulse represents the basic component of the structure of rhythm and is the fundamental unit of duration in music. According to Lerdahl and Jackendoff (1983) "beats are time points on a duration continuum" (p.18). And, when listening to music, we do not "hear" the beat; rather we experience and feel it (Kramer, 1988). The grouping of beats constitutes the meter which is periodic. The meter is usually represented by notation and bar lines, and the first beat of each bar or measure is generally accented so as to mark the meter. Beat and meter form the basic temporal organisation on which rhythmical patterns are built. Dowling and Harwood (1986) suggest that beats represent the 'cognitive frameworks' for the perception and performance of rhythm. Accent is an important feature in rhythm and it consists in the emphasis of a particular beat. On this issue, Lerdahl and Jackendoff (1983) suggest that the function of accent is for grouping durational units within the musical structure. These represent rhythmical phrases which have been defined as units by Mursell (1937) and by Cooper and Meyer (1960) as the grouping of unaccented beats around an accented beat.

It was not until the work of Lerdahl and Jackendoff (1983) that a theory of rhythmic grouping was developed. They emphasised the importance of rhythmical grouping in listeners for understanding a piece of music. On the basis of Chomsky's theory (1965,1968) on the structure of language, Lerdahl and Jackendoff find similarities between language and music. They use rhythmical grouping for defining the hierarchical organisation of music. The authors propose two main levels of organisation: one focuses on durational structure, the other on pitch structure. The durational structure consists of two elements: metrical structure and grouping structure, whereas the pitch structure involves: time-span reduction and prolongation reduction. Of particular relevance to the discussion in this thesis is the grouping structure which suggests that a continuous musical event is divided into units of 3 to 4 notes, then into phrases, and then into larger units. Lerdahl and Jackendoff speculate that rhythmic grouping occurs according to well-formedness rules, i.e., of possible structure, and preference rules, i.e., of probable structure.

Although Lerdahl's and Jackendoff's musical theory attempts to bridge the structure of music and language on the basis of Chomsky's theory, it doesn't relate directly to music, and no empirical evidence has been provided to support it. Another more accredited theory of the perception of hierarchical structure in music comes from Mari Jones and her Dynamic Attending theory (1976, 1987) which has been expanded by Drake and colleagues (2000).

According to this theory, when listening to music one might first pay attention to the low-level details which occur during short time spans, e.g., a particular motif, but then attention might shift to higher-level details, e.g., a whole movement, which takes longer to unfold. Listeners are able to respond to different temporal hierarchies because of the activation of multiple oscillators. By "oscillators" Jones means 'attentional rhythm' which she explains as the "...periodic regularity in the temporal distribution of attentional energy" (Drake et al., 2000, p.253). Therefore, Jones suggests that when listening to music together with the referent oscillator, other multiple oscillators may be activated. These multiple oscillators make it possible to create an expectancy scheme. In this perspective each oscillator is able to attune itself to the closest temporal level of the hierarchical structure. If the time level is higher than the referent oscillator, i.e., faster, it is defined as *future-oriented attending* and characterised by more predictability. On the other hand, if the time level is lower than the referent oscillator, i.e., slower, it is defined as *analytic attending* and it implies complex events which are more difficult to predict. However, the possibility of shifting attention to different levels might be less economical, in particular if the shift of attention occurs at remote levels rather than close ones. Moreover, it is easier to focus attention on higher time levels than lower ones. In fact, higher time levels are more marked and easier to predict than the lower time levels, resulting in less effortful shifts. According to Drake and colleagues (2000) multiple oscillators become increasingly available with age. In fact, as mentioned earlier, young children naturally respond to faster times, i.e., around 400ms, whereas adults prefer intermediate times, i.e., around 700ms. Therefore, with age and experience the listener becomes able to shift attention to slower and more complex time levels. Such time differences are closely examined in this thesis.

The perception of musical tempo is important because beats divide time into sections which help listeners organise their response. Fraisse (1982) argued for the importance of tempo for the perception of rhythm, as well as for the Gestalt law of proximity for the perception of succession of beats in perceptible patterns. Therefore, if the rate at which musical beats occur is too slow or too fast to be perceived and processed, it will be very difficult for the listener to respond and perform. Thus not only is rhythm strongly embedded within music, but it allows for the perception of music at different levels. In fact, different temporal components, e.g., beat and metre, mark boundaries and create units that are differently processed. All these features give shape to music in a hierarchical structure. But when the mother sings songs, does she structure her music hierarchically? And if so, does the

hierarchical structure of the music affect the mother's and the infant's participation? These are issues which the following chapters address in detail.

1.2.1 Music and its implications for infant development

During the last 3-4 months of intrauterine life the foetus is able to process auditory input and to discriminate language from music and other acoustic stimuli (Wilkin, 1991). The foetus shows changes in heart beat and motor activity when presented with sounds (Lecaunet et al., 1988). Exciting examples of early auditory memory come from DeCasper and Fifer (1980) and from Fifer (1981) who, using a non-nutritive sucking procedure, demonstrated that 2- to 4-day-old newborns prefer their mother's voice, when contrasted with other female voices.

The foetus has been found to be sensitive to musical stimuli too. In fact, when pregnant women listen to music, they report reactions from their unborn infants. Lecaunet (1996) suggested that the foetus' responses are influenced not only by the characteristics of the type of music experienced in the womb, which includes pitch and loudness, but also by the infant's current behavioural state. On this issue, Woodward (1992) observed that the foetus displayed a high percentage of heart rate acceleration in a high-variability state (active sleep), in comparison with a low-variability state (quiet sleep), when a Bach organ prelude was played at 100dB, for 15seconds.

Another important factor in the foetus' reaction to musical stimuli concerns the mother's own response. The mother's liking or disliking of a piece of music affects the infant indirectly through her psychobiological response. For example, when a group of pregnant mothers listened through headphones to 25 minutes of either classical or pop music, their infants moved more and had fewer respiratory movements in comparison to listening to silence (Zimmer et al., 1982). More importantly, these authors noted a more pronounced effect when mothers listened to their favourite music.

Using the non-nutritive sucking procedure, Panneton (1985) looked at the effect of mothers' singing on young infants. This author established that newborns prefer the intonational contour and temporal patterning of melody already used by their mothers during the prenatal period. So, for example, during pregnancy the mothers were asked to sing a melody with the syllable 'la' instead of words. After birth, their neonates were presented with two melodies: the familiar one sung during intrauterine life, and a melody which had the same notes and segmental information 'la', but a different duration, temporal order and relative number of

notes. Neonates changed their sucking pattern in order to turn on the familiar melody. With a similar technique, Satt (1984) presented 3-day-old newborns with two recorded lullabies, both sung by their mothers. They preferred the lullaby their mothers sang regularly during the last months of intrauterine life, in comparison with the unfamiliar one.

Instrumental or recorded music played during the final few months of pregnancy can also be recognised by infants after birth. For instance, Feijoo (1981) presented several times a week during the last 3 months of pregnancy the musical theme of Peter and the Wolf by Prokofiev, which he thought would be associated with a state of deep maternal relaxation. At the 37th week of pregnancy, fetuses exposed to the musical theme responded immediately with movements, whereas untrained fetuses moved only 6-10 minutes after onset of the music. Subsequently, at the time of birth in the delivery room, Feijoo played the bassoon part of the Prokofiev piece. The newborns who had previously heard the Prokofiev music in the womb were instantaneously soothed. Similarly Hepper (1988) exposed a group of mothers during the last 3 months of pregnancy to the musical theme of the Australian soap opera "Neighbours". He observed that, after birth, 4-5-day-old infants were significantly soothed and attentive to the music heard daily by their mothers during pregnancy.

From these studies it emerges that infants are not naive listeners as Trehub and Trainor (1993) suggested. Rather, infants come into the world sensitive and responsive to auditory stimuli, showing preference for sounds and voices already experienced during the final period of gestation. So the newborn's musical preferences are dictated and biased by the mother's preferences. But does the infant have his own musical preference? And if so, will the infant show a different response to his own favourite music in contrast to the mother's favourite music? I will address these issues in Chapter 6 of the thesis, but now I will briefly examine the infant's auditory development.

Although infants are very sensitive to auditory stimuli from very early in life, even before birth, their hearing system takes several months to fully reach adult auditory levels (Eilers & Gavin, 1981). For instance, an improvement in sound localisation occurs after 6 months of age at the same time as new motor developments, which reflect the maturation of higher cortical processes (Clifton 1992; Morrongiello & Rocca 1987a,b; Muir et al., 1979). Sensitivity and responsiveness to sound depends primarily on two features: loudness and frequency. Loudness, which is measured in decibels (dB), determines the intensity of a sound. The frequency of sound waves corresponds to pitch and is expressed in hertz (Hz). In

a series of studies, infants have been found to respond better to higher than lower frequencies. In particular, in comparison to adults, they show improved performance above 4000Hz (see Leventhal & Lipsitt, 1964; Olsho, 1984; Trehub, 1973). Between 6 and 24 months of age children expand their sensitivity to frequency ranges. In fact, with age they become increasingly sensitive to tiny differences in frequency, especially in the lower part of the range (Elliott & Katz, 1980).

Beyond the growing sensitivity to these basic features of loudness and frequency, the perception of sounds and music, i.e., more complex auditory signals, requires a far more sophisticated auditory system. Yet, in fact, this is already developing during early infancy. One such example is the discrimination of the pitch of complex tones in comparison with the discrimination of pure tones. According to Fassbender (1996), "complex tones possess a fundamental frequency and a number of overtones with frequencies that are multiple integers of the fundamental one. The pitch of a complex tone corresponds to the fundamental frequency and arises from the overtones" (in Deliege & Sloboda, 1996, p.66.). Using the visually reinforced head turn procedure, Clarkson and Clifton (1985) tested pitch perception of complex tones in infants of 7 to 8 months of age. These authors presented tones whose fundamental frequencies were 160, 200 and 240Hz; the only difference between tones was the number and absolute frequencies of the upper harmonics. Infants distinguished complex tones with numerous upper harmonics, and similarly to adults extracted the pitch of complex tones with and without the fundamental frequency. Another, more recent study by Saffran (2001) demonstrated that 8-month-old infants recognise absolute pitch, i.e., pure tones independently of other sounds (like musical tones), and discriminate relative pitch. The author suggested that the ability to recognise absolute pitch is important for learning and processing language but that it tends to disappear once language is acquired.

Another important feature of the sound system, which allows the listener to distinguish between two sounds with the same pitch and loudness, is timbre, measured in terms of different spectral units. In two different studies, Clarkson et al. (1988) and Trehub et al. (1990) showed that infants between 7 and 9 months of age were able to discriminate tones solely on the basis of timbre.

The ability to detect even small differences in sounds and tones is extremely important for infant development. In fact, this allows them to discriminate voices from other sounds, to detect prosody in the speech of their caregivers, and to be more attracted to "motherese" or

infant-directed speech, i.e., high pitched intonation, rather than adult-directed speech. But early auditory perception also involves the ability to order and organise sounds into meaningful configurations. 'Auditory grouping' and 'segmentation' represent the main processes involved in the organisation of acoustic stimuli. An increasing body of research has indicated that infants parse and group auditory sequences in a similar way to adults. However, according to Fraisse (1982), humans (adults and infants) display a natural tendency to segment and regroup subsets of sounds, even when the acoustic stimulus is completely uniform. Such auditory perceptual abilities are crucial for infants because they constitute part of the process of learning language. Several studies (see Hirsh-Pasek et al., 1987; Jusczyk et al., 1992; Kemler Nelson et al., 1989) have shown that infants can parse the flow of speech into units such as clauses and phrases. They achieve perceptual segmentation on the basis of prosodic information which is the most relevant feature of infant-directed speech.

This language-relevant ability may also be operative in infants' abilities to organise sequences of tones of similar frequency and of similar amplitude and spectral content (Demany, 1982; Thorpe et al., 1988; Thorpe & Trehub, 1989). This means that they are sensitive not only to the structure of speech, i.e., clauses, phrases and words, but also to the structure of music, i.e., phrases. On this point, Lerdahl and Jackendoff (1983) suggested that both music and speech are hierarchically organised in units of different duration. To examine this hypothesis, Krumhansl and Jusczyk (1990) tested a group of 4½ and 6-month-old infants, using a preferential looking paradigm, to ascertain whether they were sensitive to the phrasing structure of music. Portions of Mozart minuets with pauses within and between phrases were used. The end of the musical phrase was marked by an extended duration of the pitch, and the boundaries of phrases were stressed by a drop in pitch height. Both infant and adult participants looked/listened significantly longer to the minuet extracts that had pauses between phrases rather than within phrases. These studies indicate that infants (and adults) use similar parameters of perceptual segmentation to identify structure in processing music as they do in language. Prenatal auditory experience and postnatal exposure to infant-directed speech may well lead infants to become more sensitive to such structural units. Along these lines, Fassbender (1996) speculates that although music and language start to be processed in similar ways, they might subsequently develop differently. Indeed, music is considered to share similarities to infant-directed speech because of its wide range of pitch and temporal patterns (Rock et al., 1999). Similarly, when the mother sings she may also use a special way of singing that she would never use with adults. As such, it could be called

infant-directed singing or "songese". One of the crucial questions we will raise in this thesis is whether, when singing to their infant, mothers stress the boundaries between phrases, and whether the infant perceives structural units in songs and regulates his behaviours accordingly.

Two studies have analysed the infant's behavioural responses to music: Moog (1976) and Rock et al. (1999). Moog (1976) observed that 4- to 6-month-old infants make movements in the presence of music. In particular, he noted that they move in repetitive patterns related to the musical input, and that as the infants develop, their actions become increasingly coordinated with the musical rhythm and its dynamics. Also, whereas in the early stages infants tend to move their whole body with the musical rhythm, as they grow older their responses become more specific to particular body parts. Moog concludes that by 18 months of age infants are able to match their movements with the rhythm of music. However, Sloboda (1985) is sceptical about these results. He suggests that to display rhythmic behaviours, infants should be capable either of moving in time with the music, or of imitating a presented rhythmical pattern, or of omitting a beat and re-establishing the correct time after a pause. Little empirical research has addressed such issues in any detail.

More recent studies have demonstrated that while infants move to music, they can also organise their behaviours into cyclical patterns. In a study comparing lullabies and playsongs, Rock and colleagues (1999) explored the rhythmic motor responses of a group of 6-month-old infants. The most common rhythms found were leg kicking, head bobbing and body bouncing which the infants performed similarly in both conditions. However, contrary to the authors' predictions, the infants showed a trend towards producing more rhythmic behaviours when listening to lullabies compared to playsongs. The authors explain this response by arguing that playsongs have the function of capturing infants' attention and, when this happens, their response is to stop their ongoing activity. We will see throughout the thesis that playsongs can have a much more subtle role in mother-infant interaction.

1.2.2 Music and its implications for mother-infant interaction

1.2.2.1 Infant-directed singing

Parents and caregivers talk to their newborns immediately after birth (Rheingold & Adams, 1980). Compared to adult-directed language their speech is characterised by slow tempo, long pauses, short phrases, higher and wider pitch frequency range, elongated vowels,

rhythmic regularity and repetitiveness (Beebe et al., 1985; Fernald & Simon, 1984; Papousek et al., 1987; Stern et al., 1983). These features are typical of infant-directed speech and seem to help infants to identify the auditory stimulation addressed to them. Interestingly, as intimated above, this special infant-directed speech shares many commonalities with music, especially in its prosodic contour (Papousek M., 1996; Trainor et al., 1997). On this premise, several researchers (see Fernald, 1989; Papousek et al., 1990; Werker & McLeod, 1989) have suggested that communication with prelinguistic infants is actually mediated by musical features. Moreover, Trehub and Trainor (1993) point out that just as infant-directed speech is different from adult directed speech, so infant-directed music is different from the music with which adults are familiar.

Recent research has addressed the question of the qualities of infant-directed music. For example, Trehub et al. (1993b) recorded English-speaking and Hindi-speaking mothers singing a song of their choice in two conditions: in the presence of the infant and in the absence of the infant. Adult listeners were then asked to identify which were the infant-directed songs on the basis of the mothers' performance. Listeners from both cultures showed high accuracy in recognising infant-directed singing in their native language, but were somewhat less successful, although still significantly better than chance, in the foreign language. In another study, mothers were again asked to sing in two conditions: in the presence of the infant, and pretending to sing to an infant who was not present. Once again, adult listeners displayed great accuracy in discriminating actual infant-directed singing from simulated infant-directed singing (Trehub et al., 1993a).

Trainor (1996) carried out a similar study but this time with infant listeners, who were 4 to 7 months of age. Using a preferential looking paradigm, this author played 3 playsongs and 3 lullabies of infant-directed singing and infant-absent singing. Infants preferred infant-directed singing in comparison with infant-absent singing. Masataka (1999) ran an experiment with 15-day-old hearing newborns of deaf parents. Using a visual-fixation auditory stimuli paradigm, this researcher played infant-directed singing and adult-directed singing to the infants. The hearing infants of deaf parents preferred the infant-directed singing. From these data, Masataka concluded that infants' preference for infant-directed singing was not necessarily related to prenatal or postnatal experience, but probably to differences in the acoustic features themselves. Although this might be the case, it is obviously difficult to rule out a total absence of acoustic stimuli from the pre- and postnatal environment of hearing infants. Acoustic analysis of playsongs and lullabies (Trainor, 1996;

Trainor et al., 1997) revealed that, in comparison with infant-absent singing, infant-directed singing had slower tempo, softer voice, longer pauses between phrases, higher pitch and a 'smiling' quality. In fact, smiling modifies the vocal tract and thus influences the acoustic effect both when singing (Fonagy, 1981; Sundberg, 1973) and when speaking (Laver, 1980).

In sum, when caregivers are in the company of their infants, they sing lullabies to soothe and calm them, or sing playsongs to excite and arouse them. Playsongs and lullabies are sometimes very effective, whereas at other times they do not capture the infants' attention. According to Trehub and Trainor (1993), infants prefer some melodic contours over others in both playsongs and lullabies. In fact, some melodies are defined as 'good' because they are easily processed whereas others are 'bad' because they are more difficult to process. Adults are biased in their musical processing by exposure or formal training (Dowling & Harwood, 1986; Krumhansl, 1990), whereas infants are considered to be naive listeners. For this reason, Trehub and Trainor suggest that what infants identify as a 'good' musical pattern must be inherently good, because of their limited exposure to music. A series of studies by Trehub (1990), Trainor (1991), and Cohen et al. (1987) showed that the Western major scale contains all the rules and conventions for good melodies. Therefore they argue that "...aspects of Western major scale structure have their origins in universal constraints on auditory pattern processing" (Trehub & Trainor., 1993, p.21), which are intrinsically 'good'. Although Trehub and Trainor's theory of 'good' and 'bad' melodies might help to explain why infants prefer some musical patterns over others, their assumptions that infants are naive listeners and the proposal that Western music contains all good patterns displays a somewhat dubious cultural value judgement, a judgement that requires much stronger empirical validation. None-the-less, it is true that infants show preferences for certain types of songs and music, particularly playsongs. In the next section I focus on the structure and role of playsongs across cultures.

1.2.2.2 The use of playsongs

Although the practice of singing to infants is widespread across cultures, it is only in the last decade that researchers have investigated this phenomenon empirically (e.g., Masataka, 1999; Trainor, 1996; Trainor et al., 1997; Trehub et al., 1993; Trehub & Schellenberg, 1995). Such work has concluded that the function of playsongs is to arouse or amuse infants (Trehub & Henderson, 1994). Playsongs are characterised by a fast tempo, wide pitch range and a rich animation. The lyrics of the playsongs are also very important because they help to mark the rhythm of the song, usually accompanied by specific gestures. For instance,

songs like “Ba ba black sheep”, “Twinkle, twinkle little star” and the “ABC song”, all have the same basic melody; they differ only in text. Herzog (1950) noticed a similarity between playsongs and folk songs; both use the same melody with different texts. This seems to be particularly true of Gaelic culture, where playsongs are traditional folk songs adjusted for the purpose of interaction with infants. Various other functions have been attributed to playsongs: to promote enculturation, to convey cultural beliefs and mythology, as well as attitudes and socially accepted behaviours (Deng, 1973; Kartomi, 1980). A further function was suggested by Poueigh (1933, cited in Brakeley, 1950) who argued that playsongs serve a didactic purpose. Analysis of a collection of French Pyrenean playsongs showed that they were used to stress important phases of infant development, like the first step or the first word, as well as to help the child count.

Although mothers sing to their infants, Trehub (1994) speculated that it is actually the singers who are the main beneficiaries of their singing, and the infants are more engaged by the singers’ emotions than the songs themselves. Trehub’s hypothesis, however, does not take into account the more complex cognitive and emotional processes happening in a musical setting. In the next section, I discuss an alternative hypothesis suggested by Trainor (1996).

1.2.2.3 Why caregivers sing

Trainor (1996) offers three reasons why mothers sing differently in the presence of their infants compared to when their infants are absent or when their singing is adult-directed. Firstly, she argues that infant-directed singing serves numerous functions, of which the main one is to attract the infant’s attention. Analysis of the acoustic features of infant-directed singing reveals an especially high pitch, which might be biologically rooted. In fact, according to Morton (1977), across animal species low pitch sounds are associated with aggression and hostility, whereas high pitch sounds are related to submission, fright and friendliness. Furthermore, psychoacoustic measurements rate high-pitched voices as more attractive for infants because they carry fewer harmonics and sound less ‘rough’ (Sundberg, 1994). Secondly, Trainor (1996) suggests that infant-directed singing might also help to communicate emotions and regulate the infant’s state. In fact, music has often been regarded as having a close relationship to emotions (see Cooke, 1959; Langer, 1957; Meyer, 1956). Sloboda (1991) goes further by suggesting that music not only communicates information about emotion, but also evokes emotional responses in the listener. Therefore, in early social interaction when caregivers are mostly focused on giving comfort and regulating the infant’s

state, music appears to be the most appropriate non-linguistic form of communication. However, acoustic measurements of infant-directed playsongs and lullabies showed that the acoustic features of the mother's voice did not relate to emotions like tenderness, joy, and happiness. Trainor (1996) surmounts this objection by suggesting that the emotions communicated through infant-directed singing are not primary emotions. Rather, they constitute a complex combination of different emotions. Thus, when the mother sings playsongs she might communicate both joy and happiness simultaneously, and when she sings a lullaby she might convey both tenderness and comfort. Finally, Trainor (1996) proposes a didactic function for infant-directed singing. She suggests that infant-directed singing "concerns teaching infants about auditory pattern structure, that is, about phrase structure, rhythm and grouping" (Trainor et al., 1997, p.384).

As mentioned above, several studies have noted infants' sensitivity to phrasing structure in music (see Jusczyk & Krumhansl, 1993), and their ability to distinguish different rhythmical structures (see Demany et al., 1977; Trehub & Thorpe, 1989). One of the functions of the 'musicalisation' of infant-directed speaking may be to exaggerate its structural features so as to help infants learn language (see Kemler Nelson, Hirsh-Pasek, Jusczyk & Wright Cassidy, 1989). Furthermore, the exaggeration of clause boundaries (Bernstein Ratner, 1986), prolongation of phrase-final syllables and pauses between phrases (Trainor, 1996), are all intensified when mothers sing to their infants. This suggests that early exposure to music may actually help infants to develop auditory patterns of processing which are important for understanding and decoding the structure of both music and language.

Trainor's theory explains the relevance of music in mother-infant interaction, emphasising the cognitive and emotional processes involved in such a context. However, she does not consider the social function of music where music is a powerful medium of communication, in particular of non-verbal communication (Gaston, 1968). In the next section, I explore the relation between music and communication and why it could be important for pre-verbal infants.

1.2.2.4 The communicative function of music

In the previous sections, we discussed the relevance of music in early interaction when mothers sing to their preverbal infants. But what is actually communicated through music? Most theories (Kivy, 1980; Langer, 1953; Meyer, 1956) speculate that music communicates an emotional message. For instance, Kivy (1980), similarly to Langer (1953), suggests that

music is 'expressive' of specific moods and emotions. This means not only that composer and performer are expressing emotions while playing music, but also that music reminds us of specific emotions. Musical features are similar to prosody in language and behaviours, which also remind us of specific emotions. However, the two theorists differ in that Langer (1953) emphasises the role of music in representing a general form of emotion, whereas Kivy (1980) maintains that music represents specific emotions. A different, but more comprehensive hypothesis comes from Meyer (1956) who considered the arousal of emotions when our tendency to respond or act is arrested or inhibited. It is this prevention from doing something or from responding that results in the arousal of emotion. In the same way, when we listen to music we become aware of tonal tendencies and create an expectation of what will come next. It is on the basis of how these expectations are handled by the composer or performer, e.g., prolonged, delayed or anticipated, that we have different emotional experiences. An interesting implication of Meyer's theory is that it requires an internal mental process to account for the experience of emotions in music. And this cognitive process is based on the culture-specific style of music that the listener expects.

But what does music communicate to infants? According to Trainor (1996), when caregivers sing to their infants the message they communicate is emotional and serves to regulate the infants' state. To test this hypothesis, Rock, Trainor and Addison (1999) examined mothers' singing performance in different styles of songs. As in the experiment discussed in an earlier section on infant-present versus infant-absent contexts, the authors asked a group of mothers to sing to their 6-month-old infants a song of their choice in two styles: play-song-style and lullaby-style. Adult listeners were successful in discriminating the two different styles of singing and characterised them as: 1) play-song being more brilliant, rhythmic, clipped, full of consonants and singer more smiling; 2) lullaby being more soothing, calming and airy. Subsequently, the adult listeners were asked to watch the same videotapes, but this time without sound, and to rate the infants' response to their mothers' singing. Again the adults identified correctly what the infants were listening to solely on the basis of their behaviours: when listening to a lullaby infants looked more at themselves, whereas when listening to a playsong they looked and smiled more often at the singer. The latter results suggest that infants are more engaged in direct interaction with their caretakers when they hear playsongs. Interestingly, adult raters did not notice any difference in the infants' other motor or rhythmic activity during the two styles of song. Thus, although infants' did not show a difference in the level of their motor activity, they displayed different degrees of engagement in the two styles of songs. Rock and colleagues conclude by

suggesting that music might even be a more powerful medium than speech for communicating affect and emotions to infants.

So far I have examined the relevance of music in human life and natural responses to the rhythmical element of music. One of the functions of music is to communicate, and caregivers have been found to use different singing styles according to the message they want to convey to their infants. Furthermore, infants are sensitive to the musical stimuli, showing fine auditory discrimination and performing different responses in relation to the kind of music they are exposed to. Thus music and songs could represent an important tool for communicating with pre-verbal infants. An attempt to explain the relevance of music in interaction with young infants stems from Trevarthen (2000) who postulated the Innate Musicality theory, which I examine in the next section.

1.2.2.5 A theory of Innate Musicality

Inspired by Bernstein's work (1967) on motor co-ordination, Trevarthen (2000) proposes what he calls a theory of Innate Musicality, based on underlying impulses and motives for musical behaviours. Bernstein (1967) suggested that motor activity involving multi-jointed limbs becomes smoother and clearer when skilled and trained. He argues that "...The effort of purpose in skilled movements demonstrates both the periodic impulse or 'kinematics' of acting and the regulated 'energetics' or force of gestures. These dimensions are signatures of the brain's control of changes in body form" (Trevarthen, 2000, p.162). Trevarthen proposes that musicality is innately present in the brain on the basis of its rhythmic organisation, which allows for the co-ordination and synchronisation in space and time of different parts of the body. Trevarthen and Aitken (1994) called this Intrinsic Motive Formation, or IMF. This limbic and reticular brain system is a neural system that controls changes of the body as a single system. IMF contains the sources of neural time, and creates and combines hierarchically a variety of body motor rhythms. Related to IMF is the Intrinsic Motive Pulse or IMP, a system that controls and regulates the rhythmic movements of the body and its emotions. In Trevarthen's theory the active part of musicality is expressed by the activity of the IMF, and the IMP is its agent.

Together with motives and emotions, movements help to regulate and co-ordinate social interactions (Trevarthen, 1987). Thus, an important component of musicality is its sociability which is expressed through movement. Movement has intersubjective functions and is based on the anticipation and regulation of each other's actions and behaviours. In musicality the

movements of the body are co-ordinated and guided by pulse and rhythm which convey information about motives and emotions. Furthermore, according to Trevarthen timing and rhythm express the temporality of the brain and are not only present in adults, but also in infants. In fact, infants try to co-ordinate their actions with their mothers' vocalisations, showing sensitivity to the musical elements in their mothers' communications. Trevarthen suggests that "the timing of the impulses of expressions made by both adult and infant is the essential foundation for their mutual entrainment and the efficient anticipation they show of one another's part" (Trevarthen, 2000, p.174). Referring to Condon and Sander's (1974) study on infant entrainment with adult speech, Trevarthen notes that infants also show the same rhythmical patterns without the need for external input, e.g., parent's vocalisation (Trevarthen, 1974; von Hofsten, 1983). Furthermore, infants do not respond passively to external information but they co-ordinate stimuli crossmodally. In this way, infants and adults match intrinsic pulses, sharing actions as well as emotions and motives. So, for instance, when mothers use infant-directed speech, their infants participate by matching and co-ordinating their behaviours with the musical elements of the maternal speech represented by its prosody or song. Trevarthen (2000) likens early mother-infant interaction to experienced dancers and musicians who improvise, because both co-ordinate their vocal and physical participation in a sophisticated and accurate performance.

While Trevarthen simply offered his rather obscure theory of Intrinsic Motive Pulse without empirical support, Malloch (2000) suggests a method for seeking evidence about musicality in interaction. Through the acoustical analysis of the adult's and infant's vocal expressions, Malloch identified the elements of this 'musical dialogue' which are: pulse, quality, and narrative. The spectrographic analysis displays the pulse which occurs in "...regular successions of expressive 'events' through time" (Malloch, 2000, p.32). The pulse co-ordinates the vocal expressions of mothers and infants with regular time intervals. Quality consists in two attributes: melodic and timbre contours. Melodic contour is measured through pitch-plots and indicates the evolution of mothers' and infants' vocalisation during interaction. More complex is the timbre contour, because it is a multidimensional property of sound. Malloch also reviews other acoustic features of the voice, i.e., sharpness, roughness and width. All these properties reveal the changes in quality of mothers' responses and how they stimulate infants' vocalisation. Finally, he defines the narrative of communicative musicality which is the result of the combination of pulse and quality of gestures of the voice as well as of body.

Trevarthen's theory is an ambitious attempt to embrace different disciplines in a universal theory of music in human life. In particular, he seems to put everything related to mother-infant interaction under the umbrella of musicality. Although there are some interesting intuitions in his Intrinsic Motive Pulse theory, like timing and rhythm as the expression of the temporality of the brain guiding the co-ordination of the movements of the body, in my view emotions and motives are not the only elements conveyed through pulse and rhythm. Indeed, I would argue that together with emotional attunement, rhythm and pulse also have cognitive implications in the co-ordination and integration of temporal information. Moreover, Trevarthen's postulation is not supported by any clear evidence. Although Malloch provides a little evidence in support of the Innate Musicality theory, Trevarthen's theory requires more empirical work for either the validation or refutation of his theory.

Trevarthen is not the only author to suggest that mother-infant interaction lies at the foundation of music. Another theoretical account comes from Dissanayake (2000) who argues that music relies on the temporal organisation of early mother-infant interaction. In the next section, we turn to this interesting theoretical account.

1.2.2.6 Mother-infant interaction: from temporal organisation to music

Dissanayake (2000) compares music with the rhythmical and temporal organisation naturally present in mother-infant interactions over the first 6 months of the infant's life. On the basis of their similarities, she speculates that from an evolutionary point of view the origin of music is actually rooted in this early social interaction. First of all, like other authors Dissanayake notes some similarities between motherese and music, because they share features like rhythmic regularity and variation, speed, volume, and changes in vocal timbre. Another property common to both music and mother-infant interaction is their sequential structure which creates emotions and meanings through anticipation. These shared characteristics not only prompt bonding and social regulation but they also involve crossmodal information. Although Dissanayake emphasises the importance of rhythm in verbal and non-verbal behaviours, she believes that regular rhythmicity alone is not sufficient when the effects on early social interactions are taken into consideration. In fact, it is how the partners of the dyad co-ordinate with and respond to each other when these rhythms are modified that is the crucial quality of rhythm. This argument is proposed by Stern (1995, p.34): "mother-infant engagement and music are temporal (or sequential) structures in which changes unfolding in the present create and are the experience". These temporal episodes or units are usually variations of a melodic and rhythmic theme. Turner

(1985) and Pöppel (1985) demonstrated that the mother's utterances during interaction with her infant are mostly organised in phrases, which last around 3-4 seconds. This corresponds also to music, poetry, and phrases of prelinguistic vocalisation (Beebe & Gerstman, 1984; Krumhansl, 1992). These studies all demonstrate the importance of temporal organisation in music.

An interesting piece of research on brain-time relations comes from Pöppel (1985) who explored temporal processes in the central nervous system. Pöppel identified in particular two temporal frequencies in the brain: a) a high-frequency process of about 30ms which serves to perceive successive events and motor activity; b) a low-frequency process of about 3s which serves to integrate separate events. These two temporal intervals turn out to be very important in the processing and performance of music. The 30ms interval allows for the perception of temporal order and controls tempo during musical performance. The 3s interval, by contrast, favours the binding of separate musical elements into rhythmical patterns according to Gestalt law. Pöppel concludes that both of these temporal mechanisms are crucial in communication, especially in musical communication.

So, both Pöppel and Dissanayake stress the importance of temporal organisation processes in the brain and their relation to music. In particular, Dissanayake presents an interdisciplinary review of studies and theories on music, rhythm and mother-infant interaction. Although she offers some interesting comparisons and relations between the temporal aspects of early social interaction and music, her theorising requires empirical evidence to establish these commonalities and to explain their link to the origins of music. However, what emerges from Dissanayake's, Trevarthen's and Pöppel's theories is the tight relation between rhythm, movement and music and how they are deeply related to early social interaction between mother and infant.

1.3. Aims of the thesis

In general, studies of mother-child interaction have focused on gesture and language. In this thesis, mother-infant interaction is considered within the context of music, and it will be argued that the musical context lends itself particularly well to a more profound analysis of the temporal structure of human interaction. The above review of the literature has shown that although the role of music in mother-infant interaction has been a fairly active topic of research, many questions remain open. These will be the focus of this thesis, whose aims are:

- 1) to identify in detail the temporal structure of mothers' songs, focusing on their tempo, metrical and phrasing structure; and to examine whether mothers use a consistent musical tempo, i.e., around 500-700ms, at different ages and in different contexts. Apart from a single study by Trainor et al. (1997) this detailed analysis is missing from previous work, yet it is vital to discover whether mothers' songs provide a hierarchical structure that affects mother-infant interaction.
- 2) to identify the pattern of behaviours that mothers and infants generate during musical interaction and examine how such behaviours are distributed in relation to the phrasing structure of the songs. These behaviours involve physical actions and communicative-affective behaviours on the part of mother and infant, as well as the infant's emotional state and degree of engagement. Apart from studies by Rock et al. (1999) comparing only 4 cyclical behaviours in two types of song, previous research merely provided general statements about the fact that physical and communicative-affective behaviours accompany musical interaction, but furnished no detailed analysis of their typology. It is important to determine whether a tight relationship between music, physical movement and emotion holds for mothers and infants during mother-infant interaction, and to provide a detailed micro-analysis of these relationships.
- 3) to investigate the extent to which three types of synchronisation occur during musical interaction: synchronisation of different body parts for each separate partner, synchronisation of behaviours across the partners, and synchronisation by each partner with the musical beat. There are no previous studies that have examined different aspects of synchronisation in mother-infant musical interaction. Condon (1979) and Condon and Sander (1974) looked at infants' synchronisation in the absence of music, and Moog (1976) observed infants' synchronisation to music but did not provide clear evidence. Anticipation is fundamental to the capacity to synchronise and it is therefore crucial to ascertain how the anticipation of musical structure facilitates mother-infant interaction.
- 4) to compare mother-infant interactions that occur while taped music is being played to those that occur while the mother is singing, in order to establish whether the conclusions drawn from the above analyses also hold for a different type of mother-infant musical interaction. No previous studies have compared live songs to taped music.

1.4 Structure of the thesis

Chapter 2 will describe the methodology and procedures used in order to analyse the data related to the above issues. In Chapters 3, 4 and 5 the temporal structure of interactions when the mother sings playsongs will be analysed. In particular, Chapter 3 will identify in detail the temporal structure of mothers' songs, exploring the beat established by the mother, and the phrasing structure of the song as well as the tempo of the songs. Chapter 4 will look at the pattern of behaviours that mothers and infants generate during musical interaction, with particular attention to their levels of activity and the cyclical patterns produced, and how these relate to the phrasing structure of the songs. In Chapter 5, all aspects of synchronisation will be examined. The accuracy and level of activity performed by each partner in each kind of synchronisation will be analysed.

In Chapter 6 I will examine interactions that occur while taped music is being played, comparing the infant's favourite music to the mother's favourite music. Particular attention will be given to the musical tempo of the taped music chosen by the mothers for the two kinds of music. The level of activity and cyclical participation of mother and infant during taped music will be considered, along with their communicative-affective behaviours. I will also explore mother and infant synchronisation with respect to taped music as compared to live songs.

Finally, in Chapter 7, I will summarise and discuss the overall results from Chapters 3, 4, 5 and 6, showing how the analytic techniques and findings presented in this thesis make a new contribution to the literature on the temporal structure of mother-infant interaction. I will point to some of the advantages but also shortcomings of the more qualitative micro-analytic method and will suggest some hypotheses that might be investigated with a more controlled experimental approach by future researchers. Finally, I will give special consideration to the general question of how music contributes to the progressive structuring of the infant's social world and highlight how vital music is ... during infancy and indeed throughout the whole span of human life.

CHAPTER TWO

Methodology

This chapter focuses specifically on the methodology used throughout the thesis. It provides details of the overall empirical approach, as well as information about the mother-infant participants and the methods of analysis. It also examines inter-rater reliability for the data from the whole study. The chapter is divided into three main sections:

- 1) Section 2.1 describes of the overall setting of the research as well as the design and procedure (section 2.1.1).
- 2) Section 2.2 presents details of the protocol and procedure for coding three sets of data which include: a) the mother's and infant's physical and communicative-affective behaviours (section 2.2.1); b) tapping of beat for mother's songs and taped music as well as the transcription of the musical score (section 2.2.2); c) the infant's emotional state and degree of engagement (section 2.2.3). For each set of data assessment of inter-rater reliability is presented.
- 3) Section 2.3 discusses the methods used to analyse the coded data of section 2.2 as well as their relation to the aims of the study. In particular in section 2.3.1 the analysis of the coded data of mothers' and infants' behaviours is described, i.e., section 2.2.1, and how they serve to set the partners' level of activity and overall participation. In section 2.3.2 the comparison between the partners' behaviours (section 2.2.1) and the tapped beat for mother's songs and for taped music (section 2.2.2), allows the calculation of different kinds of synchrony: a) synchrony with self (section 2.3.2.1); b) synchrony with beat (section 2.3.2.2); c) synchrony with other partner (section 2.3.2.3).

2.1 Setting of the research

Although mothers normally sing to their infants when they are at home, most previous studies have investigated musical interactions in a laboratory setting. By contrast, a naturalistic setting at home has the advantage of making the mother more comfortable and in control of the situation. Moreover, being in his usual environment, the infant does not need to adjust to new surroundings. However, the naturalistic setting has the disadvantage of making it more difficult to control conditions as well as giving rise to the inevitable problem of increasing the number of variables. It was felt that in a novel, exploratory study of this

kind, the advantages of a naturalistic study conducted in home setting outweighed the disadvantages. Mothers were therefore asked to sing songs and play taped music of their own choice to their infants in their own home.

Participants

Because the aim of this study was to observe in very fine detail musical interactions between mother and infant, only four dyads were included. Two English-speaking mothers (henceforth: ES) and their infants were recruited with the help of colleagues from the Psychology Department at Edinburgh University; they lived in Edinburgh itself or its surroundings. Two Gaelic-speaking mothers (henceforth: GS) and their infants, based on the Isle of Lewis, core of the main Gaelic-speaking community, were recruited with the help of the local Education Department. Both groups of mothers were middle class, with secondary education or above, and were in their late twenties or early thirties. The choice of two groups from different linguistic and cultural backgrounds was made in order to avoid drawing conclusions about temporal organisation in musical interaction that might turn out to be overly culture-specific. Participant numbers were purposely kept very small (N=8 in total, four infants and four mothers) because of both the longitudinal nature of the measures and the very detailed form of data collection and data analysis. Infants were all full-term, did not have any complications at birth, and were developing normally. In both cultural groups, there was one boy and one girl.

The sessions

The ES mothers were first contacted to arrange a meeting in advance of the study at which the project, the equipment, and the terms of commitment was explained. Unfortunately, however, this proved impractical with the GS mothers, due to time and travelling constraints, and with them our first meeting had to co-occur with the first recording session. Sessions were scheduled at regular intervals when the infants were between 3 and 8 months of age. The ES mothers' appointments were always on schedule, whereas those with the GS mothers proved more problematic. Because the GS mothers lived on the Isle of Lewis, appointments were arranged so as to accommodate the needs of both mothers so that they could be visited within the same time span. Sometimes this led to a postponement of a GS session by about a week. Each session lasted about 25-30 minutes.

The apparatus

The sessions were filmed with a Panasonic video camera with concurrent high quality trace on a Sony digital audio recorder. The video camera was kept on the investigator's shoulder, rather than being fixed on a tripod, so that she could follow all the partners' movements during the entire interaction. The dyads were recorded in their homes at the most convenient time for mother and infant, and in a room chosen by the mother (usually the living room or play room).

2.1.1 Design and procedure

As mentioned in section 1.3 of Chapter 1 the foci of this thesis are:

- 1) To analyse the temporal structure of the mother's songs, with particular attention to their tempo, beat, meter and phrasing structure, as well as to examine whether they use the same tempo in interaction with their infants with both songs and taped music.
- 2) To identify the mothers' and infants' level of activity of physical and communicative-affective behaviours, focusing on how they relate to the phrasing structure of the songs, and also to examine the infants' emotional states and degree of engagement.
- 3) To understand the patterns of synchronisation of the mothers' and infants' behaviours in relation to: a) self, i.e., internal organisation of behaviours; b) the musical beat; and c) the other partner.
- 4) To compare mother-infant interaction occurring with songs with those occurring with taped music.

Because the literature on music psychology is relatively sparse with respect to developmental issues, my remaining predictions are based on existing knowledge of infant developmental outside the domain of music and on what is already known about mother-infant interaction in the context of language. Note that I have included individual dyads in the figures. This is because my study is qualitative in nature and it is thus important to highlight individual differences that would otherwise be lost in group effects.

In order to achieve these aims mother-infant interaction with songs and taped music are analysed at different ages and in different contexts and, in the case of taped music, different types of music are considered. In the following tables, details are provided of the age of the infants (Table 2.1), as well as the description of the interactions with songs (Table 2.2) and interactions with taped music (Table 2.3). In particular, in Table 2.2 on interactions with

songs, two types of comparisons are made, one across contexts and the other with a longitudinal focus. By contrast, in Table 2.3 on interactions with taped music, two types of comparisons are considered, one across contexts and the second on types of music.

Table 2.1 Infants' age in months, at each session

Session	ES1	ES2	GS1	GS2	Mean	SD
1	3.5	3.75	4	2.75	3.50	0.47
2	5.25	4.75	5.25	4	4.81	0.51
3	7	7.25	8.25	7	7.63	0.52

Table 2.1 shows that the same infants were tested at three points in time during their first year of life. The reason for doing so is that during this time infants go through rapid and crucial developmental changes. Thus, in this study I intend to examine whether these developmental changes reflect on mother-infant interaction with songs and taped music. For instance, in session 1, the infants are about 3.5-months, they are able to support their head, display the first reaching movements and are quite active. Previous studies on mothers singing to their infants involved infants from 4-6 months of age, but there are no studies of this kind with younger infants. In session 2, at about 4.5 months of age, infants can usually sit alone for a few moments, are manipulative, can reach with one hand and show sensitivity to recorded music (see Trevarthen, et al., 1981). Finally, in session 3, the infants are about 7-8 months-old, they are much stronger, can sit stably and pull themselves to a sitting position, their hand movements become more precise enabling progressive finger-to-thumb grasp of small objects (the pincer grip).

At these different points in development, how do infants participate in the interaction with songs? Is their level of activity and amount, kind of cyclical behaviours always the same or do they differ given their different levels of motor skill? Also most of the studies have focused on infants' musical perception within a limited age range, but little has been done to compare their participation at different ages.

Finally, in sessions 1 and 2, the age of the infants almost overlaps. In fact, in these sessions infants are respectively 3-4 months and 4-5 months of age. Although it is not possible to make a straightforward comparison between these two time points, the infants' participation will be assessed during interaction with songs and taped music within this particular period of infant life, i.e., 3.5 to 5 months of age.

Table 2.2 Description of contexts with songs and age range of infants

Session	Infants' range age	Song context	Description
1	2.75-4m	No-Touch 3-4m Touch 3-4m	Mother sings without touching infant Mother sings touching infant
3	7-8.25m	Touch 7-8m	Mothers sings touching infant

In Table 2.2 mother-infant interaction with songs is presented in relation to context and age. In session 1, when infants are 3-4 month-old, the interaction with the mother mainly concerns events occurring within the dyad, i.e., facial expressions, movements and sounds of each partner. Physical contact is one of the main channels for communication. The need for touching and proximity is high in both members of the dyad. To understand whether physical contact affects interaction with songs, mothers were asked to sing in two contexts: No-Touch and Touch. In the No-Touch context mothers were asked to sing without touching their infants, whereas in the Touch context mothers were told that they could now touch their infants. Mothers were free to sing songs of their choice and, although they were asked to sing the same songs in both contexts, sometimes they failed to do so and sang different songs.

In session 3, at 7-8 months of the infant's age, the interaction takes a new shape. Although previously infants could only attend either to the mother or to a toy, now they can coordinate different actions within a single sequence. Physical contact is no longer the main channels of communication. In fact, infants now increase in particular their vocalisation and babbling. Therefore, in this session there is only one song context: Touch. Mothers were told that they could touch their infants while singing. Again, mothers were free to sing songs of their choice.

Table 2.3 Description of contexts with taped music and age range of infants

Session	Infants' range age	Kind of music	Music context	Description
2	4-5.25m	Infant's music	No-Touch 4-5m Touch 4-5m	Listening to the infant's favourite music without touching infant Listening to the infant's favourite music touching infant
2	4-5.25m	Mother's music	No-Touch 4-5m Touch 4-5m	Listening to the mother's favourite music without touching infant Listening to the mother's favourite music touching infant

In Table 2.3 mother-infant interaction with taped music is presented in relation to context and type of music. Although the partners of the dyad still favour physical contact, face-to-face interaction begins to lose importance and the dyad becomes more oriented towards external objects. Not only do infants at this time show interest in recorded music, but Trehub and Trainor (1993) found that infants also display preferences for certain musical contours

and melodies. On the basis of these earlier findings we asked the mothers to play what they consider to be the infant's favourite music as well as their own favourite music. Moreover, because physical contact is still an important aspect of mother-infant interaction at 4-5 months mothers were asked to play the two types of taped music in two contexts: No-Touch and Touch.

2.2 Coding the data

In this section details of how the data were coded as well as the protocol used to code the data are presented. Three sets of data were collected and differently coded. They concern: a) measurement of the mother's and infant's physical and communicative-affective behaviours in musical interaction (section 2.2.2); b) identification of the beat of the mother's songs and taped music through tapping of the beat (section 2.2.3); and c) assessment of the infant's emotional state and degree of engagement during musical interaction (section 2.2.4). Before explaining the various coding systems, an overview of the relation between coding and the aims of the thesis is given in section 2.2.1.

2.2.1 Overview of coding

In section 2.2.2 the mother's and infant's physical and communicative-affective behaviours have been coded in order to identify their level of activity as well as to quantify their attempt to communicate in musical interactions. These data will help to determine how mother and infant relate to interaction with songs and taped music. Within physical behaviours, particular attention is given to the mother's and infant's cyclical behaviours which represent the rhythmical component of their participation. Because the focus is on the amount of physical and communicative-affective participation, these behavioural data are measured in terms of onset and offset times, i.e., their duration. On the other hand, these data are also crucial for the assessment of synchronisation. Three types of synchronisation are examined: a) with self, which consists of a comparison of the onset time behaviours performed by each partner, b) with the musical beat, which consists in the comparison between onset time behaviours and beat, c) with the other partner, in which case the onset times of mother's and infant's behaviours within the same dyad are compared. For the purpose of synchronisation, only the onset times of the partners' physical and communicative-affective coded behaviours are considered. Moreover, in order to understand how the partners of the dyad synchronise with the musical beat and with the other partner, their kinds and categories of synchronous behaviours are considered. Kinds of behaviours refer to single, cycle, and communicative-

affective behaviours the partner performs in order to match with either the beat or the other partner. Categories of behaviours, by contrast, cover the parts of the body involved in synchronisation and they differ slightly between mother and infant. Mother's category of synchronous behaviours includes: head and body, hand and leg, behaviours in contact with infant, and toy. Infant's category of synchronous behaviours includes: head and body, hand, leg, behaviours in contact with mother, and toy.

In section 2.2.3 the identification of the beat of the mother's songs and taped music is achieved with the assistance of a musician. This is crucial for the reconstruction of the song and in particular its temporal structure, e.g., phrasing structure, as well as the identification of the musical tempo of the songs and taped music. In order to make these measurements, beat duration is taken into consideration. The beat is essential to determine whether each partner of the dyad synchronise with the musical event. In this case, onset times of the partner's behaviours and onset times of the beat are compared.

In section 2.2.4 the infant's emotional states and degree of engagement are assessed in order to evaluate the infant's states in interaction with songs and taped music. Infant's emotional states and degree of engagement are assessed and the duration of each state reported.

2.2.2 Coding the mother's and infant's physical and communicative-affective behaviours

In this section the protocol for the mother's physical behaviours (section 2.2.2.1), and the infant's physical behaviours (section 2.2.2.3), as well as the protocol for the mother's (section 2.2.2.2) and the infant's (section 2.2.2.4) communicative-affective behaviours are reported. Section 2.2.2.5 follows with the explanation of the procedure applied to code the mother's and the infant's physical and communicative-affective behaviours. Finally, in section 2.2.2.6 the procedure for assessing the inter-rater reliability of the coded behaviours and results of this assessment are presented.

The protocol of physical behaviours was developed specifically for the purposes of this study and it focuses on the partner's single gestures and cyclical actions. The latter are particularly interesting because they represent the rhythmic aspect of the dyad's participation. By cyclical actions is meant a repeated movement which starts from one point and ends more or less at the same point. An example of a cycle is head nodding, which corresponds to down-up-down

or up-down-up movements. By contrast, a single gesture is a unidirectional movement, like head up.

Two different protocols were created: one for the mother and one for the infant. The mother's protocol includes 59 categories, and the infant's protocol consists of 63 categories. Appendix lists the mother and infant protocols used for coding the data.

2.2.2.1 The mother's physical behaviours

The mother's physical behaviours include: head, body, leg, hand movements, as well as activity involving contact with the infant's body and limbs, and activity with a toy.

Head movements: Cyclical head actions include nodding and shaking. In particular, nodding includes not only the vertical direction, but also horizontal movements, i.e., backward-forward-backward. Single head gestures encompass: up, down, side, backward from the infant, and forward to the infant.

Body movements: The mother's body actions include all the movements she makes independently of physical contact with her infant, either while sitting or standing. Cyclical body actions include: bouncing, rocking and swaying. Single body gestures include: body forward, backwards and to the side.

Leg movements: This category includes mother's leg and foot movements where right leg/foot and left leg/foot are coded separately. Cyclical leg actions include: bouncing, waving, and tapping (foot only). Single leg gestures include: up, down and side.

Hand movements: This category includes mother's hand and finger movements. Right hand/finger and left hand/finger are coded separately. Moreover, when the mother moves the fingers of her hand, each finger is coded individually. The mother's hand/finger cycles can be either in contact or not in contact with the infant. The mother's hand/finger cycles in contact with the infant include: caressing, patting, and tickling (finger only). The mother's hand/finger movements not in contact with the infant include: waving, shaking, circling and clapping hands. No single gestures are considered under this category.

Activity involving contact with the infant's body and limbs: This category includes the movements that the mother makes in contact with the infant's body and limbs. The mother's cyclical actions in contact with the infant's body include: bouncing, waving, rocking, swinging and 'flying'. The mother's cyclical actions in contact with the infant's limbs include: waving, shaking, circling, cycling and irregular (when the cyclical movement lacks a clear direction). Similarly to the previous categories, when the mother produces activity

with the infant's limbs, each limb is considered independently. The mother's single gestures in contact with the infant's body includes only up. On the other hand, the mother's single gestures in contact with the infant's limbs include: up, down and side. Again the limbs are looked at individually, coding left and right limb separately for each category.

Activity with a toy: This category includes the mother's activity when holding a toy. The mother's cyclical actions with toys include: shaking, bouncing and banging. The mother's single gestures with toys include: up, down and side.

2.2.2.2 The mother's communicative-affective behaviours

As well as the mother's physical behaviours, her communicative-affective behaviours were also coded and included: touching the infant, kissing, face-to-face contact with the infant, and smiling.

Touching the infant: The mother's physical contact with her infant includes a brief touching or longer holding. Other actions in this category include: touching the infant's body, face, or limbs; in the latter case, right and left limb are treated separately.

Kissing: This includes affectionate kissing gestures of the mother during the musical interaction.

Face-to-face contact: This includes affectionate gestures of the mother by touching the infant's face with her own face.

Smiling: This includes facial expressions where the corners of the mother's mouth are in an upward position.

2.2.2.3 The infant's physical behaviours

The protocol of the infant's behaviours include: actions of the head, body, arm, and leg, and with a toy. Similarly to the mother's coding, the infant's physical and emotional behaviours are coded in parallel. Because sometimes the mother's activity in contact with the infant provokes movement in the infant's body, these latter movements are not coded as the infant's spontaneous activity.

Head movements: The cyclical actions of the head include nodding and shaking. The single head gestures include: up, down, side, backward and forward.

Body movements: This category includes the infant's activity with his trunk when either lying down or sitting on the floor. The cyclical actions with the body include: bouncing,

rocking, and twisting. The single body gestures include: up, down, side, forward to or backward from the mother.

Arm movements: This category includes the infant's movements with arm, hand and fingers. The right and left arms are coded independently. The cyclical actions with the arm include bouncing and circling-waving. The single arm gestures include: up, down, side, forward (to try to reach the mother or a toy), backward (towards his own body).

Leg movements: This category includes the infant's movements with leg and foot, when the infant is lying on the floor or sitting on the mother's lap. The cyclical actions with the leg include: kicking and cycling-waving. The single leg gestures include: up, down, side, bend, and stretch.

Actions with a toy: This category includes the activities the infant performs when holding a toy. The cyclical actions with the toy include: bouncing, shaking and circling. The single toy gestures include: up, down, and side.

2.2.2.4 The infant's communicative-affective behaviours

The category system for the infant's communicative-affective behaviours was inspired by Murray's (1980) PhD thesis and adapted for the purposes of the present study. It includes: touching, mouth gestures, and smiling.

Touching: This category includes every physical contact the infant makes with the mother, self, and a toy. Because the infant could touch any of these with either of his hands or his legs, each part of the body is coded separately: left hand, right hand, left leg, right leg.

Mouth gestures: Murray (1980) suggested that by observing the infant's mouth gestures it is possible to identify the infant's Communicative Effort. For the purpose of this study the focus is on the infant's Active Communicative Effort which includes the following mouth gestures: protruding tongue, mouth wide open, and mouth shaped.

Smiling: This category includes facial expressions where the corners of the infant's mouth are in an upward position.

2.2.2.5 Coding procedure

The procedure for coding the mother's and infant's behaviours was inspired by Burford's study (1993). Burford suggested that in order to code the partners' behaviour during an interaction, it is necessary to concentrate on each of the partners separately, and code only one behaviour at a time across the whole duration of the interaction. When the coding of that

behaviour is finished, one then passes to another behaviour and examines that through the whole interaction again. In this way, each partner's behaviour is examined and coded separately, and the same interaction is watched as many times as the number of the mother's and the infant's coded behaviours.

In order to code a behaviour, it is necessary to watch the video at a very slow speed, so as to mark correctly onset and offset times. In this way the audio part of the video disappears, making the coding more objective. However, sometimes it is necessary to watch the video at a normal speed to understand the evolution and trajectory of a behaviour. If the behaviour remains unclear even at a normal speed, it is discarded. The mother's cyclical movements are generally neater and easier to code compared to the infant's. However, the onset of the mother's hand and finger cycles in contact with the infant's body and limbs are more difficult to identify. For this reason it was decided to code those actions from the very first point of contact with the infant's body and limbs.

Coding onset and offset time

The onset time corresponds to the very beginning of the behaviour, i.e., the first frame in which it occurs. For instance, when the infant lifts his leg, the onset counts from the very first frame when the infant begins to move his leg. The offset time marks the very end of the behaviour, i.e., the first frame in which the action is completed.

Coding behaviours hidden from view

Because of the naturalistic setting of our study, sometimes it happened that the behaviour was not clearly visible. If the behaviour was hidden from view, it is accompanied in the coding by 'VH', i.e., view hidden. Marking the events hidden from view is important not only for reliability purposes, but also to indicate that the partner could have shown more behaviours if the view had been clearer. The different kinds of hidden views include:

- 1) The whole interaction is completely hidden from view (coded as: VH). In this case the onset time, i.e., the first obscured frame, and offset time, i.e., the first frame in view, are coded with VH plus onset and offset times, but no behaviour is identified. This occurred rarely.
- 2) Only part of the body is hidden from view (coded as: VH + part of the body hidden from view). For example, the infant would put his hand behind the mother's body, thus away from the video camera. Thus the infant's hand is totally hidden from view and impossible to code,

although the rest of the interaction is perfectly in view. In this case, the part of the body hidden from view is noted with VH.

3) It could be that only a particular behaviour is hidden from view (coded as: behaviour + VH). For example, the mother tickles the infant's face on the cheek away from the camera. In this case, although it is possible to guess the action, because of the uncertainty of the assessment it is marked as hidden.

4) Finally, only the very beginning or the very end of a behaviour is hidden from view and the rest of the action is totally visible. In this case, the observed behaviour is marked with view hidden, either with respect to the onset time if the behaviour was hidden at the very beginning (coded as: onset time behaviour + VH), or with respect to the offset time if the behaviour was hidden at the very end (coded as: offset time behaviour + VH).

Interruption of a behaviour: end or pause?

Sometimes the interruption of an action makes it difficult to decide whether the following action is a continuation of the same movement or the beginning of a new one. In this case, two factors are taken into consideration: the context in which the action happens, and the separation time between two events. First, the context is considered. In this case it is important to watch the video at a slow to medium speed, and not frame-by-frame as usual, to reconstruct the action. For instance, if the infant lifts his left arm, then stops, and shortly thereafter continues an action on the same upward left arm trajectory, this is taken as an indication that the infant is just pausing during the course of a single movement. However, sometimes the context is not sufficient to disambiguate, and in this case, time differences are used. When the separation time between two events is less than 1 second, it is regarded as a pause interrupting a single movement, but if the gap is more than 1 second, two separate events are coded.

2.2.2.6 Inter-rater reliability for the mother's and infant's behaviours

Assessment of the inter-rater reliability for the mother's and infant's behaviours focused on their cyclical actions, because cyclical actions represent the most rhythmical component of their behaviours in musical interaction. Although the raters coded both onset and offset times of the mother's and infant's cyclical behaviours, onset times were considered sufficient for inter-rater reliability purposes for cyclical behaviours. Agreement between coders is considered to occur when they both code the onset time of each cyclical behaviour within a one-second temporal window.

The author coded all the data. A graduate student volunteer acted as a second coder for a subset of the data so that inter-rater reliability could be assessed for the mother's and infant's cyclical behaviours. The rater was instructed to identify first the infant's cyclical actions and later the mother's cyclical actions. First of all, the rater was acquainted with the equipment, the protocol and the procedure for coding. To ensure that the rater could identify the cycles correctly and code their onset times accurately, a week of training was provided on practice parts of the videos. When the rater showed accuracy and felt confident of her coding, she proceeded independently to rate the infant's cycles in musical interaction. The rater took five weeks to code the cyclical behaviours of the infant. Similarly, a further week of training was necessary for coding the mother's cyclical behaviours, after which coding took about 6 weeks. Musical interactions were selected so as to be representative of the different dyads, contexts, ages, and types of music. The same songs and pieces of taped music were coded for the mothers and the infants.

The inter-rater reliability of the mothers' and infants' cyclical behaviours were measured on 12 out of 46 songs (i.e., 26%), and 8 out of 20 pieces of taped music (i.e., 40%). Kappa coefficient tests were applied to the onset times of the two coders' data. Table 2.4 provides the results of the inter-rater reliability tests relevant to the data discussed in Chapters 4, 5 and 6. They show high levels of reliability.

Table 2.4 Kappa results of inter-rater reliability for onsets of cyclical actions

Mother	Category	Kappa	p value	Infant	Category	Kappa	p value
	Overall	0.83	.0001		Overall	0.80	.0001
	Head	0.74	.0001		Head	0.69	.0001
	Body	0.74	.0001		Body	0.79	.0001
	Leg	0.82	.0001		Leg	0.84	.0001
	Hand	0.82	.0001		Hand	0.73	.0001
	In contact with infant	0.82	.0001		Toy	0.72	.0001
	Toy	0.77	.0001				

2.2.3 Coding the musical beat

In section the procedure to identify and code the musical beat of the mother's songs and taped music (section 2.2.3.1), the transcription of the musical score (section 2.2.3.2) and the assessment of the coded beat through inter-rater reliability (section 2.2.3.3) are explained.

2.2.3.1. Identification of the musical beat

In order to understand how the mother's and infant's behaviours relate to music and whether they synchronise with the musical beat, it was necessary to make this set of data comparable. For this reason, it was decided to superimpose the musical beat on the musical interaction so as to create exactly the same temporal reference. The beat was identified with the help of an orchestra conductor who, because of his training and profession, is an expert in identifying the temporal structure of music, and in particular the beat. He was asked to tap the tempo established by the mothers, marking the beat of the songs and of the taped music of their choice. His tapping finger was video-recorded while he listened to the musical event. He could only hear the musical piece or song; he could not see any of the other aspects of the interaction between the mother and her infant. The conductor was allowed to listen to the musical event as many times as necessary to understand the variations in style and structure of the mother's songs, as she adapted to the interaction. Once the conductor was ready, his tapping was recorded, and then the conductor and researcher both checked that the tapping correctly matched their perception of the mother's tempo. Sometimes the conductor found it difficult to tap the very first beat of the songs. Indeed, unless the mother was taking a deep breath in, or making some acoustically distinctive sound to anticipate and mark the fact that she was about to embark on singing, it was difficult to identify the very beginning of the musical event. In such cases, the mean duration of the beats in that particular musical event was used to fill in any missing data.

2.2.3.2 Musical score and beat

The musical scores of the mothers' songs were transcribed with the help of another musician. As in the case of the beat, it was important that the musician transcribed only what the mother actually sang, rather than what she should have sung according to musical conventions. The beats tapped by the musician, together with the transcription of the musical score, made it possible to rebuild/describe the structure of the mother's song and its temporal organisation.

2.2.3.3 Inter-rater reliability of the tapped beat

Inter-rater reliability was measured on 12 out of 46 songs (i.e., 26%) and 4 out of 20 pieces of taped music (i.e., 20%). In order to assess inter-rater reliability for the tapped beat, a professional drummer was also asked to tap the beat. He received exactly the same

instructions as the conductor and could also only perceive aurally the taped music or the song sung by the mother, without any visual information about the mother-infant interaction. Kappa coefficient tests were applied to assess the degree of agreement between the two musicians. Agreement was defined according to both a strict and a lenient criterion. Under the strict criterion, the two musicians' tapping onset times had to occur within 40ms (i.e., one frame) of each other; while under the lenient criterion, they had to occur within 80ms (i.e., two frames). The reason for selecting these two temporal windows is that the same two latencies will be used in later analyses to define synchronisation of the mothers' and infants' behaviours with the musical beat (see Chapters 5 and 6). Kappa values of 0.83 ($p < 0.0001$) and 0.89 ($p < 0.0001$) were obtained, for latencies of 40ms and 80ms respectively. Thus, the beat data are very robust and reliable.

2.2.4 Coding the infant's emotional state and degree of engagement

In this section, I coded the infant's emotional states and degree of engagement. In particular, section 2.2.4.1 focuses on the setting and procedure used to determine the infant's states, whereas section 2.2.4.2 reports the assessment of the inter-rater reliability of this coding and the results.

2.2.4.1 Setting and procedure

Although mothers are assumed to be in positive emotional states and fully engaged during interactions involving music, infants are not. In order to assess the infant's emotional states and degree of engagement, it was important to take into consideration the infant's participation as a whole. For this purpose, the coder was asked to assess the infant's emotional state and degree of engagement while watching the video at normal speed and to mark every change. The equipment consisted of a computer-linked Video-logger program, slider, and a video-recorder. The slider is a mouse-driven slider bar that can be moved forwards and backwards. Each movement of the slider corresponds to a score between 0 and 255, where 0 is at the lower end of the slider and 255 at the upper end. It works on a continuum, and each move is scored on the computer together with the corresponding time code of the video.

The coder sits in front of the TV monitor which shows the videotape to be analysed. Next to the monitor, a computer running the Video-logger program displays any slider change with its corresponding score and time code. The program's mouse-driven slider bar is set up

differently according to the kind of assessment needed, i.e., emotional state or degree of engagement. The coder is asked to evaluate the infant's emotional state according to 5 categories: very unhappy, unhappy, neutral, happy, very happy. In this case the slider is set to score the 'neutral state' in the middle (score 102 to 152), from 'happy' (score 153 to 203) to 'very happy' (score 204 to 255) in the upper part, and from 'unhappy' (score 51 to 101) to 'very unhappy' (score 0 to 50) in the lower part. The middle part of the slider bar is marked to help the coder recognise the neutral zone by touch, without the need to look down at the slider, thus maintaining the focus on the infant.

The coder is also asked to assess the infant's degree of engagement according to 4 categories: no engagement (score 0 to 63), little engagement (score 64 to 127), engagement (score 128 to 190), and high engagement (score 191 to 255). In this case, the slider is set up to score 'no engagement' in the lower part, to 'high engagement' in the upper part, via 'little engagement' and 'engagement'.

The viewer thus coded one infant at the time, focusing either on his emotional state or degree of engagement and then, when this was completed, the coder assessed the next infant.

2.2.4.2 Inter-rater reliability of the infant's emotional states and degree of engagement

The inter-rater reliability of the coding of the infant's emotional states and degree of engagement was assessed with the help of an undergraduate student who served as a second rater. The rater was familiarised with the equipment, the sessions and the tasks. When the rater felt confident about the equipment and understood the task, the coding started. In this case half a day of training was sufficient. The coder assessed all the sessions following the same procedure as the author.

The author's and the coder's data were correlated using the Pearson parametric correlation coefficient. Because of the nature of the data, in which the slider works on a continuum where events are scored only when a change occurs, the data had to be put into an appropriate format for purposed comparison. Overall, Pearson correlations for inter-rater reliability of the infants' emotional states is $r= 0.96$, $df= 271$, $p= .0005$, and of the infants' degree of engagement $r=0.85$, $df= 271$, $p= .0005$. Therefore, coder and author show high levels of correlations on the assessment of both the infants' emotional states and their degree of engagement.

2.3 Analysis of musical interaction

In this part of the chapter, I present the procedures used to analyse the data to be presented in the following results chapters. First of all, in section 2.3.1 attention is given to the mother's and infant's physical and communicative-affective behaviours, in a similar fashion as the data coded in section 2.2.2. This will serve to determine how the partners of the dyad relate to interaction with songs and taped music, focusing in particular on their level of activity, amount and kind of cyclical behaviours they produce in different contexts, age and different types of music. The results of these measurements will be presented in Chapters 4 and 6. Then, in section 2.3.2, examples are given of the analyses of the mother's and infant's synchronisation with self, the musical beat and the other partner (40ms and 80ms latencies). Synchronisation is an important phenomenon which requires the anticipation of the next event as well the partner's ability to co-ordinate his actions in relation to the target event, e.g., the musical beat. Onset times of the data coded according to the coding system explained in sections 2.2.2 and 2.2.3 will be compared as a function of the kind of synchronisation considered. In section 2.3.3, an example of the analysis of the musical tempo, temporal structure, and phrasing structure of a song are reported. The results of this kind of analysis will be discussed in Chapters 3 and 6, although in the latter the focus will be on the tempo of the musical pieces. Finally, in section 2.3.4, an example of the analysis of the coding of the infant's emotional states and degree of engagement is shown. The results of these assessment will be presented in Chapters 4 and 6.

2.3.1 Analysis of the mother's and infant's physical and communicative-affective behaviours

In the following sections the procedures used to calculate the duration of the mother's and infant's physical (section 2.3.1.1) and communicative-affective (section 2.3.1.2) behaviours in musical interactions are explained. Moreover, in section 2.3.1.3 how the infant's emotional state and degree of engagement were calculated are reported. The same procedure was used for interactions both while the mother was singing and while she was playing taped music.

2.3.1.1 Mother's and infant's physical behaviours

The total amount of activity is measured on the assumption that the partner could move different parts at the same time. In fact, the mother could simultaneously move her head,

body, both hands and legs, her infant and a toy, i.e., 8 parts, except in the no-touch context where she could potentially move only 7 parts because she is not allowed to touch her infant. On the other hand, the infant could simultaneously move: head, body, both arms and legs, and a toy, i.e., 7 parts. The total duration of the interaction is multiplied by the number of parts that each partner could move. This gives the potential overall amount of activity the partner could produce if she/he were to move all parts all the time. The actual amount of behaviour for each partner is then expressed as a percentage of his/her potential overall amount of activity. For instance, when the ES1 mother sings to her 3-4 month-old infant in the touch context, she moves her head in one direction for 0.32s, and her hand for 4.08s in single gestures and for 0.72s in cyclical activity. Therefore, the sum of the durations of her behaviours is 5.12s, in a total musical interaction of 16.68s. However, it must be pointed out that 5.12s does not correspond necessarily to the total amount of time during which she moves; in fact some of her behaviours are simultaneous or overlapping. Because she could potentially move 8 parts during the whole interaction, 16.68s multiplied by 8 gives 133.44s which corresponds to the overall amount of potential activity of the ES1 mother. At this point we relate her actual amount of activity, i.e., 5.12s, to the potential amount of activity i.e., 133.44s, which means that the ES1 mother produces 4% of the total amount of potential activity. The cyclical activity of the partner is expressed as a percentage of the overall amount of actual activity. In our example, the ES1 mother moves only her hand in cycles for 0.72s, which corresponds to 14% of her overall amount of activity of 5.12s.

2.3.1.2 Mother's and infant's communicative-affective behaviours

The mother's communicative-affective behaviours include: touching her infant, smiling, face-to-face contact and kissing her infant. Although most of these behaviours are measured in relation to the overall duration of the interaction, touching the infant is measured differently. In fact, because the mother could simultaneously hold and touch her infant with both hands during the whole interaction, touching involves 3 parts. Thus it is calculated the potential overall amount of touching by multiplying the duration of the interaction by the number of parts with which the mother could potentially touch her infant. The actual amount of touching is then expressed as a percentage of the mother's potential overall amount of touching her infant. For instance, during an interaction of 26.08s, the GS1 mother touches her infant with each hand 26.08s, and the infant's body 14.48s. Hence her total touching is 66.64s. Because her potential touching is 78.24s, i.e., 26.08 multiplied by 3, the percentage of her touching the infant is 85%.

The infant's communicative-affective behaviours include: 1) active Communicative Effort (CE) which occurs when the infant's mouth is wide open or shaped, or when he protrudes his tongue, 2) Touching which refers to 'mother' when the infant makes contact with his hands and/or feet with the mother's body, 'self' when he touches his own mouth or body, and 'toy'; and, 3) Smiling. Although the infant's smiling and active CE are measured in relation to the overall duration of the interaction, touching is measured differently. In fact, touching involves three categories, i.e., mother, self and toy. Furthermore, the infant could simultaneously touch with both hands and both feet. Therefore touching is measured in relation to the overall touching activity performed by the infant within an interaction. For instance, if the ES1 infant touches his mother for 23.10s and himself for 2.01s, his overall touching is 25.11s. In this case the percentage of touching is 92% (i.e. 23.10s multiplied 100/25.11s), and touching himself is 8% (i.e., 2.01s multiplied by 100/25.11s)

2.3.1.3 Infant's emotional state and degree of engagement

In section 2.2.4 I explained the procedure to code the infant's emotional states and degree of engagement. Both emotional states and degree of engagement were coded and for each of them any change was scored. The infant's emotional states include five categories: very unhappy, unhappy, neutral, happy and very happy. The infant's degree of engagement includes four categories: no engagement, little engagement, engagement and high engagement. For each interaction based around song and taped music, the infant's emotional states and degree of engagement were measured as a percentage of the overall duration of the interaction. For instance, in an interaction lasting 17.16s the infant displays a neutral state for 13.04s and happy state for 4.12s. In this case the infant shows 76% neutral state (i.e., 13.04s multiplied by 100/17.16s) and happy state 24% (i.e., 4.12s multiplied by 100/17.16) during the whole duration.

2.3.2 Analysis of the mother's and infant's synchronisation

As mentioned earlier synchronisation represents an important phenomenon not only in life but also in interaction. In this study three types of synchronisation are examined and in the following sections examples of how the onset times of the partners' behaviours were compared in relation to the type of synchronisation considered. In section 2.3.2.1 will be examined the partner's synchronisation with self, i.e., internal co-ordination. In section 2.3.2.2 synchronisation of the partner's behaviours with the musical beat will be considered.

Finally, in section 2.3.2.3 synchronisation of the partner's behaviours with the other partner's behaviours.

Synchrony is considered to happen when the distance between onsets of events is within two temporal windows: 1) 40ms, and 2) 80ms. 50ms is the temporal latency found by Condon and Sander (1974) when infants entrain with their mothers' speech and body movements. However, because in this study the duration of each frame is 40ms, in order to have synchronisation within a temporal window of 50ms only one frame must occur between onsets. Therefore, it was decided to apply Condon and Sander's temporal parameter, i.e. 50ms (in our study 40ms) and also to consider a larger temporal window, i.e., 80ms, which allows two frames of discrepancy between onsets events. The mean distance between the onset times of events not only serves to determine whether synchronisation occurs, but also helps to define the accuracy of the partner's synchronisation.

In the cases of synchronisation with the musical beat and with the other partner are also explained in relation to the temporal structure of the song. Below examples are given of the comparison procedure between onset-time events which made it possible to identify synchronisation.

In the following tables, are provided examples of the data from the musical interaction between the GS1 mother and her 3-4-month-old infant when she sings a Gaelic song during the no-touch context. For the sake of brevity, only the first two phrases of the songs are displayed, with the onset times of the behaviours shown.

2.3.2.1 Self synchrony

Table 2.6 shows the GS1 infant's self synchronisation, i.e., when she co-ordinates her behaviours internally. The columns of the table report, from the left hand side: 1) the coded behaviours of the infant; 2) the onset times, in chronological order of the infant's behaviours expressed in seconds; 3) synchrony at 40ms, which indicates that the distance between onset times occurs within a 40ms latency; 4) synchrony at 80ms, when the distance between the onset times of two behaviours occurs within a 80ms latency.

Table 2.6 Example of self synchronisation within 40ms and 80ms temporal windows

Infant's behaviours	Onset Time (in seconds)	Synchrony40ms	Synchrony80ms
L leg down	0.72		
L leg side	2.08		
R hand waving	3.24		
L hand down	3.40		
L leg down	3.84		
R leg side	4.20		
Head up	4.32		
L arm up	4.44	0ms	
R leg up	4.44	40ms	
L leg bend	4.48		
R hand side	4.80		
L hand waving	5		
L leg side	5.20		
L leg down	5.56		
Head up	5.76		
R arm forward	6	40ms	
L arm down	6.04		80ms
L leg side	6.12		
L leg down	6.48		

The example in Table 2.6 shows that the GS1 infant co-ordinates several of her actions. In fact, out of 19 behaviours she displays 5 behaviours in self-synchrony within 40ms latency, i.e., 26% of her overall activity within 2 phrases of the song. Overall the mean distance between onset time synchronous behaviours is 27ms. When an 80ms temporal window is considered, the GS1 infant performs only one extra action in self synchrony. Thus out of 19 behaviours, she co-ordinates 6 of them at 80ms latency, i.e., 32%, of her overall activity within the first two phrases of the song. Overall the mean distance between onset time synchronous behaviours is 40ms. This same procedure is applied to the mother's behaviours.

2.3.2.2 Synchronisation with the musical beat

In this section synchronisation with the musical beat is examined. Again, the same example is used as presented in the previous section of musical interaction between the GS1 mother and her 3-4-month-old infant during the no-touch context. Only the first two phrases of the song are considered.

Table 2.7 provides an example of the GS1 infant's synchronisation with the musical beat. The columns of the table report, from the left hand side: 1) the behaviours of the infant together with the musical beats; 2) the onset times in chronological order of the infant's behaviours and musical beats, expressed in seconds, 3) synchrony at 40ms, which indicates that the distance between onset times occurs within a 40ms latency; 4) synchrony at 80ms, when the distance between the onset times of a behaviour and of a beat occurs within a 80ms latency.

Table 2.7 Example of synchrony with the musical beat within 40ms and 80ms temporal windows

Infant's behaviours and beats	Onset Time (in seconds)	Synchrony40ms	Synchrony80ms
1st beat (1st phrase)	0.68	40ms	
L leg down	0.72		
2 nd beat	1.08		
3 rd beat	1.40		
4 th beat	1.76		
L leg side	2.08		
5 th beat	2.20		
6 th beat	2.60		
7 th beat	2.96		
R hand waving	3.24		
8th beat	3.36	40ms	
L hand down	3.40		
1st beat (2nd phrase)	3.80	40ms	
L leg down	3.84		
2nd beat	4.16	40ms	
R leg side	4.20		
Head up	4.32		
L arm up	4.44		
R leg up	4.44		
L leg bend	4.48		80ms
3 rd beat	4.56		
R hand side	4.80		
4th beat	4.96	40ms	
L hand waving	5		
L leg side	5.20		
5 th beat	5.32		
L leg down	5.56		
6^h beat	5.72	40ms	
Head up	5.76		
R arm forward	6		
L arm down	6.04		80ms
L leg side	6.12	0ms	
7 th beat	6.12		
L leg down	6.48	0ms	
8th beat	6.48		

In this example, out of 19 of the GS1 infant's behaviours 8 are in synchrony with the musical beat within a temporal window of 40ms, i.e., 42%, of her overall activity in the first two phrases of the song. Overall the mean distance between infant's synchronous behaviours and beat onset time is 30ms. On the other hand, when 80ms latency is considered, the example shows that the infant synchronises 10 behaviours with the musical beat, i.e., 53%, of her overall activity. Overall the mean distance between onset time synchronous behaviours and beat is 40ms.

Temporal structure of synchronisation with musical beat

A more detailed analysis of the same example would reveal that at 40ms latency, the infant produces two synchronous behaviours with the beat in the 1st phrase and six synchronous behaviours with the musical beat in the 2nd phrase of the song. At 80ms latency, the infant performs two behaviours in synchrony with the beat in the 1st phrase, and eight behaviours in synchrony with the beat in the 2nd phrase of the song. Except for one cyclical behaviour with

the hand, all the synchronous behaviours are single gestures and they are mostly produced with the legs and hands. At 40ms latency, the GS1 infant synchronises on the 1st (twice), 2nd, 4th, 6th, 7th, 8th (twice) beats. At 80ms latency, the GS1 infant synchronises on the 1st (twice), 2nd, 3rd, 4th, 6th, 7th (twice) and 8th (twice) beats.

2.3.2.3 Synchronisation between mother and infant

In this section, the mutual synchronisation of behaviours between mother and infant during a musical interaction is examined. Again the musical interaction between the GS1 mother and her 3-4-month-old infant during the no-touch context is used as the example. As with the previous examples, only the first two phrases of the song are discussed here. Table 2.8 shows the GS1 dyad's synchronisation with each other. The columns of the table report, from the left hand side: 1) the mother's (in capital letters preceded by 'M') and the infant's (in lower case, preceded by 'B') coded behaviours in chronological order; 2) the onset times, in seconds, of the mother's and infant's behaviours; 3) synchrony at 40ms latency, when the distance between the mother's and infant's behaviours occurs within a 40ms temporal window; 4) synchrony at 80ms latency, when the distance between the mother's and infant's behaviours occurs within a 80ms temporal window.

As the example in Table 2.8 below shows, at 40ms latency, out of 7 behaviours, the GS1 mother matches 3 behaviours with her infant, i.e., 43% of her overall participation in the first 2 phrases of the song. On the other hand, out of 19 behaviours the GS1 infant synchronises 3 behaviours with the mother, i.e., 16% of her overall amount of participation in the first 2 phrases of the song. In this example, the partners' overall mean distance between onset time of synchronous behaviours is 27ms.

Table 2.8 Example of synchrony between mother and infant within 40ms and 80ms temporal windows

Mother's and infant's behaviours	Onset time (in seconds)	Synchrony 40ms	Synchrony 80ms
1 st phrase	0.68		
B l leg down	0.72		
M Head nodding	1.84		
B l leg side	2.08		
M Head up	2.44		
B r hand waving	3.24		
M Head nodding	3.36	40ms	
B l hand down	3.40		
2 nd phrase	3.80		
B l leg down	3.84		
B r leg side	4.20		
B head up	4.32		
B l arm up	4.44		
B r leg up	4.44		
B l leg bend	4.48		
B r hand side	4.80		
M head nodding	4.96	40ms	
B l hand waving	5		
B l leg side	5.20		
B l leg down	5.56		
M Head up	5.76	0ms	
B head up	5.76		
M Head side	5.92		80ms
B r arm forward	6		
B l arm down	6.04		
B l leg side	6.12		80ms
M Head up	6.20		
B l leg down	6.48		

Taking our example one step further, when an 80ms latency is taken into account the GS1 mother synchronises 5 of her behaviours with the infant, i.e., 71%, of her overall activity in the first 2 phrases of the song. The GS1 infant, by contrast, matches 5 out of 19 behaviours with her mother, i.e., 26% of her overall participation in the first two phrases of the song. Overall the mean distance of the mother's and infant's onset time of synchronous behaviours is 48ms. With respect to the phrases of the song, it emerges that in the 1st phrase both partners match only one behaviour with each other at 40ms latency. By contrast, in the 2nd phrase the partners produce 2 (at 40ms latency) and 2 (at 80ms latency) synchronous behaviours with the other partner.

2.3.3 Analysis of the tapped beat

In this section an example is presented of how the tapped beat of the mother's song was used to identify the temporal structure of the song. In Table 2.9 a song sung by the GS1 mother to her 3-4 month-old daughter during the no-touch context is presented. The table reports three pieces of information, from the left hand side: 1) the beat position which indicates the beats of the phrase of the song, and the type of beat, i.e., upbeat/downbeat, 2) the beat onset time

which indicates the onset time of the tapped beat, and 3) the beat duration which indicates the distance between successive rows.

Table 2.9 Example of tapped beat of a song and beat duration

Beat position and type	Beat onset time (in seconds)	Beat duration (in seconds)
1 st phrase		
1 st (downbeat)	1.04	0.40
2 nd (upbeat)	1.44	0.28
3 rd (downbeat)	1.72	0.40
4 th (upbeat)	2.12	0.36
5 th (downbeat)	2.48	0.44
6 th (upbeat)	2.92	0.40
7 th (downbeat)	3.32	0.44
8 th (upbeat)	3.76	0.40
2 nd phrase		
1 st (downbeat)	4.16	0.40
2 nd (upbeat)	4.56	0.44
3 rd (downbeat)	5	0.40
4 th (upbeat)	5.40	0.40
5 th (downbeat)	5.80	0.36
6 th (upbeat)	6.16	0.40
7 th (downbeat)	6.56	0.44
8 th (upbeat)	7	0.40
3 rd phrase		
1 st (downbeat)	7.40	0.36
2 nd (upbeat)	7.76	0.40
3 rd (downbeat)	8.16	0.40
4 th (upbeat)	8.56	0.44
5 th (downbeat)	9	0.44
6 th (upbeat)	9.44	0.44
7 th (downbeat)	9.88	0.40
8 th (upbeat)	10.28	0.40
4 th phrase		
1 st (downbeat)	10.68	0.40
2 nd (upbeat)	11.08	0.40
3 rd (downbeat)	11.48	0.44
4 th (upbeat)	11.92	0.40
5 th (downbeat)	12.32	0.40
6 th (upbeat)	12.72	0.40
7 th (downbeat)	13.12	0.40
8 th (upbeat)	13.52	0.40

As Table 2.9 shows, the song sung by the mother is a 4-line stanza with 8 beats per phrase. The overall mean beat duration is 0.40s, which corresponds to *allegro* metronome tempo. The mother sings very regularly; in fact her modal tempo is 0.40s (SE 0.01s). The duration of the phrases of the song which is obtained by adding the beat duration within the phrase corresponds to: 1st phrase 3.12s, 2nd phrase 3.24s, 3rd phrase 3.28s, and 4th phrase 3.24s. Therefore, the total duration of the mother's song is 12.88s, and the phrase duration ranges between 3.12s and 3.28s, where the 1st phrase is the shortest whereas the 3rd phrase is the longest.

2.3.4 Analysis of infant's emotional state and degree of engagement

In this section, an example of how the coded data described in section 2.2.4 are analysed, as shown in Table 2.10. In this case the analysis refers to the assessment of the GS1 infant's emotional state during the no-touch context at 3-4 months. The same procedure is applied to the assessment of the infant's degree of engagement. The three columns displayed indicate, from the left hand side: 1) onset and offset times of the musical interaction (expressed in seconds from the beginning of the videotape), 2) time marked when a change in the infant's state is observed, and 3) score of the assessment of the infant's emotional state which ranges between very unhappy, i.e., -2 value, and very happy, i.e., +2 value, passing through unhappy (-1), neutral (0) and happy (+1).

Table 2.10 Example of the coded data for the infant's emotional state

Onset and offset time musical interaction (in seconds)	Time marked	Value emotional state
203.80s	-	0
	205.96	0
	212.68	0
217.56s	-	0

As Table 2.10 shows, during the musical interaction the coder marked only two variations which happened within the same emotional state, i.e., '0' which indicates neutral state. Therefore, during this musical interaction, the GS1 infant shows 100% neutral state. Because the emotional state is measured on a continuum from the beginning to the end of the videotape, at the onset and offset times of the musical interaction, there is no time marked by the coder which means that the infant is in the same emotional state as previously.

2.4 Overview of the chapter

In this chapter, different issues related to the methodology used in the research presented in this thesis were examined. First of all, the exploratory nature of this study was emphasised. Because so little research has hitherto been done on mother-infant musical interaction, an in-depth, semi-experimental approach was chosen in order to achieve the aims. Instead of analysing one or two behaviours on a large population, it was decided to opt for a small number of mother-infant dyads to be able to carry out a micro analysis of a wide range of behaviours in musical interactions. The results of this detailed ground work can be used by future researchers to generate hypotheses for a more experimental approach on a larger population.

The coding systems adopted for this project, together with the protocol of the mother's and the infant's behaviours, were presented. Detailed information about the procedures used to codify the partner's behaviours was provided. Despite the fact that the coding system was very detailed and complicated, Kappa coefficient tests revealed very high inter-rater reliability between coders. The identification of the beat of the songs and taped music was obtained with the help of an orchestra conductor and a drummer. High agreement was found between the musicians, at both 40ms and 80ms temporal windows. Details were also provided of the procedure used to assess the infant's emotional states and degree of engagement. Pearson correlations showed high inter-rater reliability between coders.

In the third part of the chapter details were given of the principal analyses adopted in this research. Those analyses are the bases of the results chapters that follow. First of all, I described how the mother's and the infant's physical and communicative-affective behaviours were measured, followed by detailed examples of how these data were employed to determine synchronisation with self and the other partner, as well as their comparison with the tapped beat, for synchronisation with the musical beat. Secondly, I explained how the tapped beat served to measure the tempo and temporal structure of the songs and musical pieces. Finally, an example of the assessment of the infant's emotional state was shown.

In the following chapters these procedures will be used to report the results of the overall study. In particular Chapters 3, 4 and 5 will focus on the mother's and the infant's participation in interactions where the mother is singing, whereas Chapter 6 will concentrate on mother-infant interactions where taped music is being played.

CHAPTER THREE

Songs and their temporal structure in early interaction

This chapter examines the temporal structure of musical interactions when mothers sing to their infants. In section 3.1 I focus on the tempo of the songs, and in section 3.2 on the temporal structure of the songs with particular attention being paid to metre organisation (section 3.2.1), and phrasing structure (section 3.2.2).

3.1 The tempo of songs during interaction

As pointed out in Chapter 1, previous studies have observed that during interaction, mothers establish a beat in order to keep the infant's attention. However, the various studies led to inconsistent findings. On the one hand, Beebe et al. (1982) found that mothers' cycles occurred mostly at around 250 and 600ms, with a wide range from 250 to 2000ms. In a more recent study, on the other hand, Gratier and Devouche (2000) noted that in interaction with 8-10 week-old infants, mothers' behaviours cluster around an 800ms interval. Similarly, Trevarthen (2000) suggested that in protoconversations with infants of around 6 weeks of age, the beat established by the mother corresponds to a slow *adagio* tempo of around 900ms. It is only a couple of months later that we witness an acceleration of the beat to a *moderato* tempo of around 500ms (Sylvester-Bradley & Trevarthen, 1978).

The above findings relate to verbal and non-verbal interaction between mother and infant. This chapter asks whether the same will hold for musical interaction. Will the mother perform a consistent and regular tempo when she sings to her infant at different ages and in different contexts? Given that physical contact is one of the main channels of communication in the first few months of the infant's life, what is the role played by physical contact in musical interaction? Moreover, the infant goes through rapid changes during the first year of his life which involve his own development as well as interaction with his mother. Will it be possible to detect those changes in interaction with songs at different infant ages? Is there any relation between the musical tempo of the songs and its phrasing structure? Given that the musical tempo determines the pace of the song, will it also affect the duration of the phrases in relation to their position?

It is known that all over the world caregivers sing songs, in particular playsongs, to their newborns immediately after birth as well as to the developing infant (Rheingold & Adams, 1980; Trehub et al. 1993). When analysing playful mother-infant interaction, Trevarthen (1986) observed that mothers sing nursery rhymes and songs, perform action games and dance with their infants from 3 months of age onwards. Trainor (1996) noted that the tempo of the playsongs sung by mothers to their 4-to-7-month-old infants corresponds to a bit duration of around 500ms. Similarly, Bergeson and Trehub (1999) found that when mothers sing songs to their 6-11-month-old infants, the mean beat is also around 500ms. However, Trevarthen (1987) situates the tempo somewhat more broadly, suggesting that when singing to their 3-month-old and older infants, the mothers' beat is centred around a *moderato* tempo, ranging between 500 and 700ms. It is thus generally agreed that when singing to their infants, the mothers' mean beat occurs around 500-700ms which corresponds to the indifferent zone identified by Fraise (1964, 1982). In fact, Fraise argued for the existence of internal clocks or pacemakers which regulate the pace of perceived and produced information at around 500-700ms. However, previous studies on tempo did not manipulate context and age of infant to verify the generality of the findings.

On the basis of Fraise's theory (1964, 1982) I hypothesise that mothers will offer a tempo around 500-700ms in different contexts and at different ages. To test this hypothesis, musical interactions at 2 ages: 3-4 months and 7-8 months are compared. At 3-4 months two contexts are contrasted during interaction with songs: no-touch versus touch contexts. Then 2 ages are compared during the touch contexts in interaction with songs: 3-4 months versus 7-8 months. In order to test this hypothesis, the mean beat duration, standard error, and modal tempo of the mother's songs are analysed.

3.1.1 The identification of the mother's beat

In section 2.2.3 of Chapter 2, I described in detail how the mother's beat was identified with the help of a conductor who tapped the beat. It was further explained how the temporal structure of the song was determined through identification of the beat and transcription using musical notation. These procedures were applied to every song sung by the mother; repetitions were considered independently.

The identification of the beat is also very important for understanding the tempo established by the mother through her singing. In fact, tempo corresponds to the pace at which the beats occur, which is expressed by the traditional Italian terms *andante*, *moderato*, *allegro*, etc.

However, tempo can be measured precisely with a metronome whose markings show the number of times a certain note value, usually the crotchet, occurs in the space of one minute. An example of a typical metronome indicator is the crotchet note played at 80 per minute, i.e., M.M.=80, where M.M. is an abbreviation which stands for Maezel's Metronome, from Maezel who, in 1816, constructed the metronome (Radocy & Boyle, 1997). In Table 3.1 the metronome tempo, its markings (number of beats in one minute), and the corresponding beat duration are shown. They provide the temporal measurements that will be used in this study.

Table 3.1 Metronome tempo, metronome markings and beat duration

Metronome Tempo	Metronome markings number of beats per minute	Beat duration (in seconds)
Largo	30-60	2.00s to 1.00s
Larghetto	61-66	0.99s to 0.90s
Adagio	67-76	0.89s to 0.78s
Andante	77-108	0.77s to 0.56s
Moderato	109-120	0.55s to 0.50s
Allegro	121-168	0.49s to 0.36s
Presto	169-208	0.35s to 0.28s

3.1.2 The mothers' songs

The songs sung by the mothers consist of 4-line stanzas, which usually represent the whole song. However, sometimes mothers sang more complex songs including chorus and verse, but again with a 4-line stanza structure. The aim was to select songs for analysis (starting from the beginning of each interaction) until a corpus of songs with a total duration of 70-80s was obtained for each mother in each condition. However, it was not possible to reach this target for the condition where mothers sang to their 3-4 month old infants in the no-touch context, since in this condition the mothers all sang for a time shorter than one minute. A total of 46 song performances were selected for analysis; this corresponded to 16 different songs since many of the songs were repeated.

In Table 3.2 I identify by title and kind the songs sung by each mother. These songs constitute the database for the present study, shown in Table 3.3. Because these songs are part of the mother's own repertoire, sometimes they were repeated, either in the same context or across several contexts.

Table 3.2 Songs sung by the mothers

Mother	Title	Type
ES1	1) Rock-a- bye baby	Lullaby
	2) Baa baa black sheep	Nursery rhyme
	3) Old MacDonald had a farm	Children's song
	4) Frere Jacques	French nursery rhyme
	5) Humpty Dumpty	Nursery rhyme
ES2	1) Wonderful Baby (by Don McLean)	Song from film theme music adapted for the infant
	2) Ally Bally	Children's song
	3) Emily, Emily, Emily is the best baby	Song created for the infant on a football tune
GS1	1) Haoi o haoirium thunna mise raoirm thu	Scottish reel- dance
	2) Cluasan, suilean, suon is beul	Scottish reel tune/dance adapted for infant
	3) Cluinn an tainich, cluinn an tainich	(Gaelic version of Frere Jacques) playgroup song
	4) tune from Broch leam	Scottish reel
	5) Hob, hob Charlie	Infant's song
	6) Suas	Scottish reel
GS2	1) Brochan leam, Tana leam	Gaelic song (song about porridge)-work song
	2) Calum beag an t-siucar	Gaelic song (originally Domhnall Beag) adapted for the infant

Overall the songs sung by the mothers are mostly nursery rhymes or baby songs. It is interesting to note that some mothers sing 6 kinds of songs whereas others only 2, with an average of about 4 songs per mother. It is clear that individual mothers produce different styles. For instance, the ES1 mother presents quite traditional songs, in that she sings mainly infant songs, nursery rhymes, and lullabies. Quite unconventional is the ES2 mother who, aside from one infant song, adapts songs to her infant. For example, "Wonderful baby" is a song that comes from a film. Moreover, she also adapts a football tune to the infant's name: Emily. By contrast, the GS mothers emphasise their cultural background. Both these mothers chose traditional Gaelic songs which are not particularly baby songs, but are part of their general culture. However, like the ES2 mother, the GS2 mother adapts one song "Calum beag" to the infant's name.

Table 3.3 Database of interactions based around songs used for this study

Mother	No-Touch 3-4 months	Touch 3-4 months	Touch 7-8 months
ES1	Rock-a-bye-baby	Rock-a-bye baby Rock-a-bye baby Baa baa black sheep Baa baa black sheep	Frere Jacques Frere Jacques Humpty Dumpty Humpty Dumpty Humpty Dumpty Humpty Dumpty Ally Bally Ally Bally Ally Bally Wonderful Baby Wonderful Baby Wonderful Baby Tune
ES2	Wonderful Baby Wonderful Baby	Wonderful Baby Wonderful Baby Ally Bally	Hob, hob Charlie Hob, hob Charlie Hob, hob Charlie Hob, hob Charlie Suas Suas
GS1	Haio o haoirium thunna mise raoirm thu Haio o haoirium thunna mise raoirm thu	Cluinn an tainach, cluinn an tainach Cluinn an tainach, cluinn an tainach Cluasan suilean, suon is beul	Brochan leam, Tana leam- Chorus Brochan leam, Tana leam, Tune (Chorus) Brochan leam, Tana leam, Tune (Chorus) Brochan leam, Tana leam, Tune (Verse) Calum beag an t-siucar (Chorus) Calum beag an t-siucar (Chorus) Calum beag an t-siucar (Verse)
GS2	Brochlan leam, Tana leam	Brochlan leam, Tana leam Calum beag an t-siucar (Chorus 1) Calum beag an t-siucar (Chorus 2) Calum beag an t-siucar (Verse 1) Calum beag an t-siucar (Chorus 3)	

3.1.3 The mothers' musical tempo

In each condition the mothers sang only a few songs which were often repeated. Because each song has its particular style and tempo, I report for each mother the songs she sung, as well as her repetitions. In the following tables the musical tempo, mean beat duration, standard error, and modal tempo are presented for every mother in each singing context. The procedure to identify this information is explained in Chapter 2, section 2.3.3. The mean beat duration and musical tempo was identified through the tapping of the musician. Standard error is measured in relation to beat duration, and modal tempo is calculated by categorising each beat as corresponding to a particular tempo and then determining which tempo is the most frequent.

Table 3.4 Mothers' temporal performance in the 3-4 months no-touch context

Mother	Title song	Musical tempo	Mean beat duration	SE	Modal tempo
ES1	Rock-a-bye baby	largo	1.08s	0.06s	largo
ES2	Wonderful Baby	andante	0.69s	0.02s	andante
	Wonderful Baby	andante	0.67s	0.01s	andante
GS1	Haio o haoirium thunna mise raoirm thu	allegro	0.40s	0.01s	allegro
	Haio o haoirium thunna mise raoirm thu	allegro	0.40s	0.02s	allegro
GS2	Brochlan leam, Tana leam	allegro	0.40s	0.00s	allegro

First, it emerges that when they are not allowed to touch their infants, mothers sing only one song which sometimes is repeated. Secondly, there is a clear distinction between the ES and

GS mothers with respect to the tempo of the songs. The ES mothers sing songs at a relatively slow tempo, i.e., *largo* and *andante*. By contrast, the GS mothers favour a fast pace singing lively songs at an *allegro* tempo.

Table 3.5 Mothers' temporal performance in the 3-4 months touch context

Mother	Title song	Musical tempo	Mean beat duration	SE	Modal tempo
ES1	Rock-a-bye baby	<i>largo</i>	1.18s	0.07s	<i>largo</i>
	Rock-a-bye baby	<i>largo</i>	1.12s	0.05s	<i>largo</i>
	Baa baa black sheep	<i>allegro</i>	0.44s	0.02s	<i>allegro</i>
	Baa baa black sheep	<i>allegro</i>	0.49s	0.03s	<i>allegro</i>
ES2	Wonderful Baby	<i>andante</i>	0.67s	0.02s	<i>andante</i>
	Wonderful Baby	<i>andante</i>	0.69s	0.02s	<i>andante</i>
	Ally Bally	<i>allegro</i>	0.42s	0.01s	<i>allegro</i>
GS1	Cluinn an tainach, cluinn an tainach	<i>andante</i>	0.56s	0.02s	<i>andante</i>
	Cluinn an tainach, cluinn an tainach	<i>andante</i>	0.57s	0.01s	<i>andante</i>
	Cluasan suilean, suon is beul	<i>allegro</i>	0.49s	0.08s	<i>allegro</i>
GS2	Brochlan leam, Tana leam	<i>andante</i>	0.68s	0.04s	<i>andante</i>
	Calum beag an t-siucar (Chorus 1)	<i>allegro</i>	0.39s	0.06s	<i>presto</i>
	Calum beag an t-siucar (Chorus 2)	<i>presto</i>	0.32s	0.04s	<i>presto</i>
	Calum beag an t-siucar (Verse 1)	<i>presto</i>	0.28s	0.01s	<i>presto</i>
	Calum beag an t-siucar (Chorus 3)	<i>presto</i>	0.27s	0.00s	<i>presto</i>

When there is physical contact, mothers produce longer performances and often repeat the same song. The tempo of the songs ranges between *largo* and *presto*. However, it is interesting to note that every mother sings songs both at slow and fast tempos. Also mothers repeat the same song at least once, and most repeat the song at the same tempo. However, in this respect the GS2 mother shows a different pattern. In fact, when she sings the song 'Calum' she performs the first chorus at fast *allegro* tempo but when she repeats the chorus she speeds up to *presto*. Furthermore, every time she sings either a chorus or a verse she increases the pace of the song. She is the only mother who sings in this pattern in this context.

Table 3.6 Mothers' temporal performance in the 7-8 months touch context

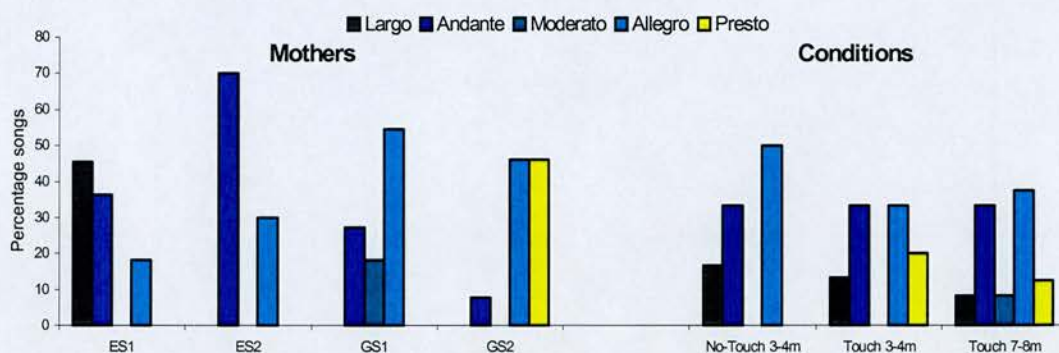
Mother	Title song	Musical tempo	Mean beat duration	SE	Modal tempo
ES1	Frere Jacques	<i>largo</i>	1.11s	0.05s	<i>largo</i>
	Frere Jacques	<i>largo</i>	1.01s	0.01s	<i>largo</i>
	Humpty Dumpty	<i>andante</i>	0.72s	0.10s	<i>andante</i>
	Humpty Dumpty	<i>andante</i>	0.69s	0.10s	<i>andante</i>
	Humpty Dumpty	<i>andante</i>	0.69s	0.06s	<i>andante</i>
	Humpty Dumpty	<i>andante</i>	0.69s	0.14s	<i>andante</i>
ES2	Ally Bally	<i>allegro</i>	0.47s	0.00s	<i>allegro</i>
	Ally Bally	<i>allegro</i>	0.46s	0.00s	<i>allegro</i>
	Ally Bally	<i>allegro</i>	0.48s	0.00s	<i>allegro</i>
	Wonderful Baby	<i>andante</i>	0.60s	0.02s	<i>andante</i>
	Wonderful Baby	<i>andante</i>	0.65s	0.02s	<i>andante</i>
	Wonderful Baby Tune	<i>andante</i>	0.63s	0.02s	<i>andante</i>
GS1	Hob, hob Charlie	<i>allegro</i>	0.49s	0.01s	<i>allegro</i>
	Hob, hob Charlie	<i>allegro</i>	0.49s	0.04s	<i>allegro</i>
	Hob, hob Charlie	<i>moderato</i>	0.50s	0.04s	<i>allegro</i>
	Hob, hob Charlie	<i>allegro</i>	0.48s	0.02s	<i>allegro</i>
	Suas	<i>andante</i>	0.60s	0.10s	<i>andante</i>
	Suas	<i>moderato</i>	0.55s	0.03s	<i>moderato</i>
GS2	Brochan leam, Tana leam- Chorus	<i>allegro</i>	0.38s	0.00s	<i>allegro</i>
	Brochan leam, Tana leam, Tune (Chorus)	<i>allegro</i>	0.43s	0.00s	<i>allegro</i>
	Brochan leam, Tana leam, Tune (Chorus)	<i>allegro</i>	0.40s	0.00s	<i>presto</i>
	Brochan leam, Tana leam, Tune (Verse)	<i>presto</i>	0.35s	0.06s	<i>presto</i>
	Calum beag an t-siucar (Chorus)	<i>allegro</i>	0.39s	0.07s	<i>presto</i>
	Calum beag an t-siucar (Chorus)	<i>presto</i>	0.32s	0.05s	<i>presto</i>
	Calum beag an t-siucar (Verse)	<i>presto</i>	0.33s	0.05s	<i>presto</i>

During the touch context at 7-8 months, mothers produce several performances, often repeating the same song. Similarly to the context when they sang and played with their 3-4-month-old infants, mothers appear to sing both fast and slow songs for the older infants too. For example, when the GS1 mother sings 'Hob hob Charlie', during the first two performances she sings at an *allegro* tempo, but the third time she slows down slightly singing at a *moderato* tempo, and in the final version she increases her speed to an *allegro* tempo again. Also when the GS1 mother sings 'Suas', in the first version she sings at an *andante* tempo whereas the repetition is slightly faster at a *moderato* tempo. Similarly, when the GS2 mother sings 'Broch leam', she performs the first three times at *allegro* whilst the last version is sung at a *presto* tempo. And finally, when she sings 'Calum', the first time is at an *allegro* tempo, and then she speeds up the following two versions to a *presto* tempo. It could be that, by slightly changing the tempo of songs that infants are already familiar with at a specific tempo, the GS mothers are aiming to create musical tension for playful purposes or to hold their infants' attention. Interestingly, the ES1 and GS1 mothers display a higher standard error when singing to the older infant compared to the other mothers and to the previous contexts with younger infants. This suggests that although those mothers preserve the same tempo they introduce small variations in order to stimulate their infants' attention.

3.1.4 Mothers' most common tempos

In the previous section we have seen that mothers not only sing different songs, but also sing them at different tempos. In this section, I explore the most common tempos performed by each mother when singing to her infant. In Figure 3.1 a summary of the percentage of performances at each tempo for each mother and in each condition are displayed.

Figure 3.1 Most common musical tempos used by the mothers



The most common tempos sung by the mothers to their infants are *allegro* and *andante*. These two tempos are not only the most common across mothers, but they are also used by every one of the mothers. Moreover, it is interesting to observe that the ES mothers sing songs more often at an *andante* tempo than at an *allegro* tempo. On the other hand, the GS mothers display the opposite pattern in that they sing songs more often at an *allegro* tempo than at an *andante* tempo. Finally, the ES1 mother often sings songs at a slow *largo* tempo, whereas the GS2 mother often sings at a very fast *presto* tempo.

3.2 Temporal structure of music

As discussed in Chapter 1, crucial aspects of the temporal organisation of music are: beat, meter (the grouping of beats into bars), and phrase. Beat forms the structural component of rhythm and represents the basic unit of duration (Radocy & Boyle, 1997). The grouping of beats represents the meter. It is the succession of strong and weak beats that creates metre and thus the perception of grouping (Radocy & Boyle, 1997). Usually the first beat of each bar is accentuated, i.e., lengthened. Accent and lengthening of duration are considered to be perceptually equivalent by Fraisse (1982). It is the perception of different levels of meter in both music and language that led theorists to define meter in terms of a hierarchy (Martin, 1972; Yeston, 1975). Just as speech can be divided into clauses, clauses into phrases, phrases into words, and words into syllables, so Lerdahl and Jackendoff (1983) proposed that music

can be divided into sections, sections into phrases, phrases into melodic and rhythmic figures, and melodic and rhythmic figures into notes. However, it was Krumhansl and colleagues who, in a series of different studies, found that the lengthening of tone duration, changes in melodic line, as well as in tone and harmonics, contribute to the perceptual discrimination of music into units (see Clark & Krumhansl, 1990; Palmer and Krumhansl, 1987a,b). Furthermore, Krumhansl and Jusczyk (1990) demonstrated that 4.5- and 6-month-old infants can discriminate the phrasing structure of music, suggesting that the perceptual segmentation of music is not specific to adults. Here I ask whether, in the context of singing, the mother places special emphasis on this hierarchical structure of music.

Trainor et al. (1997) analysed the clarity of musical structure when mothers sang infant-directed versus infant-absent lullabies and playsongs to a group of infants between 4 and 7 months of age. They found that the mothers increased the duration of the final syllable plus the inter-phrase pause in playsongs, but only in the infant-present context. They also found that the relative duration of stressed syllables was greater compared to unstressed syllables in playsongs with infant-directed but not infant-absent singing. One study has thus hitherto suggested that mothers exaggerate the structure of music when they sing playsongs, provided that the infants are present. The Trainor et al. study did not examine other aspects of music like metrical structure of the mothers' songs, nor did they assess whether mothers need to touch their infants to display such a structure organisation. Moreover, they did not examine whether the infant's age is an important aspect for the mothers to emphasise the temporal structure of the song. Here I examine whether mothers stress the metrical and phrasing structure of their songs, and, if so, how? When mothers sing to 3-4 month olds, does the temporal structure of their songs differ between no-touch and touch contexts? Does mothers' phrasing structure change in relation to context, age or musical tempo? Does the mother change style when singing to 7-8 month-old infants compared to 3-4-month-olds?

On the basis of Lerdahl and Jackendoff's theory (1983), discussed in Chapter 1, I hypothesise that mothers will emphasise the hierarchical structure of songs when singing to their infants. It is the succession of stronger and weaker beats in the meter that characterises speech and music, and makes them both perceived as layered, i.e., hierarchically organised (Handel, 1989; Martin, 1972; Yeston, 1975). In particular, this allows for a grouping hierarchy which consists of the segmentation of stronger and weaker beats into units and phrases (Lerdhal & Jackendoff, 1983). Therefore, it is predicted that the mothers will stress the succession of strong and weak beats, by 'accenting' the first beat of each bar more than

the other beats (Radocy & Boyle, 1997). Traditionally in Western music the 1st beat of the bar, i.e., the downbeat, represents the 'first accented note' of the piece, whereas the following beat is the 'upbeat' (or pickup) (Dorr, 1995). Because in this study mothers sang mostly with an 8-beat phrase structure, the 1st and 5th beats are supposed to be longer than the others. Furthermore, on the basis of Trainor and colleagues' work (Trainor et al., 1997) I hypothesise that the mother will mark the boundary of the phrase by lengthening the duration of the last beat. Although it is expected that mothers will emphasise the hierarchical structure of songs so that they are perceived as layered by extending the duration of some phrases and reducing the duration of others, no specific prediction regarding which phrase will be lengthened is made in relation to context, age and musical tempo. Finally, according to Trehub and Schellenberg (1995), caregivers adapt their singing style to the age of the infant. In particular, they sing a solo performance to their younger infants, whereas towards the end of the first year of the infants' life singing becomes more dialogic together with changes in the structure of the song. Thus, I hypothesise that the way mothers modify the structure of their songs will be different when singing to 7-8-month-olds compared to 3-4-month-olds.

In order to test these hypotheses, the songs the mothers sang while interacting with their infants in two contexts and at two different ages are contrasted. The two contexts of no-touch versus touch were compared with respect to the songs the mothers sang during interactions with their 3-4 month-old infants. The two ages (3-4 months versus 7-8 months) were compared with respect to the mothers' singing in the touch context. Because the majority of the songs sung by the mothers present phrases with 8 beats, the analysis is based on this particular phrasing structure. The beat duration was measured in 8-beat phrase structures, paying particular attention to downbeats and upbeats which were then compared. Moreover, other grouping structures were measured within the phrase, in particular the duration of the 8th beat at the end of the phrase compared to the other beats. Finally, the duration of the phrases in 4-line stanzas in the songs and in relation to the musical tempos was determined.

3.2.1 The song structure: meter organisation

So far I have discussed the length of the beat in relation to the pace at which mothers sing to their infants. Now I look at whether the length of a beat varies according to its position in a phrase. This is important because it reveals how mothers structure the phrases of the song. As mentioned before, because the majority of the songs sung by the mothers present phrases with 8 beats, the analysis is based on that phrasing structure. The remaining 11 songs, although not included in the analyses of the beat, are included in all the other analyses.

Figure 3.2 Mean duration of beat, expressed in seconds, by position in phrase, as a function of mother, collapsed across contexts and ages

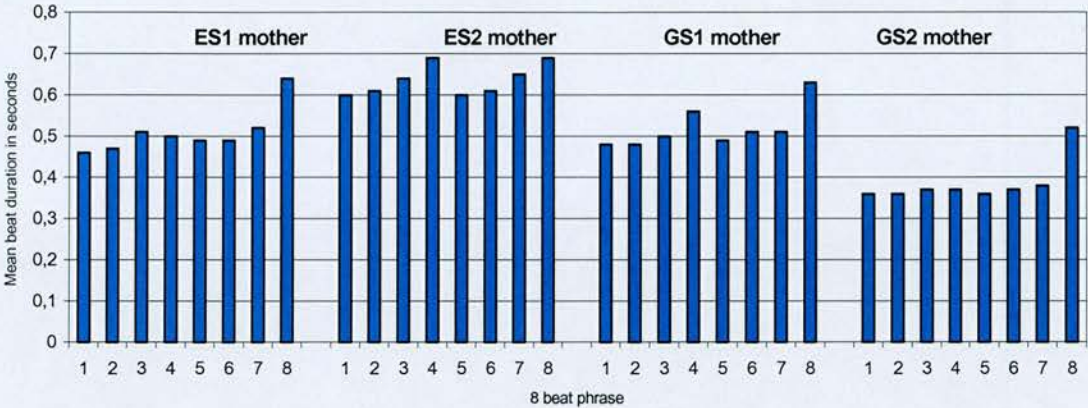
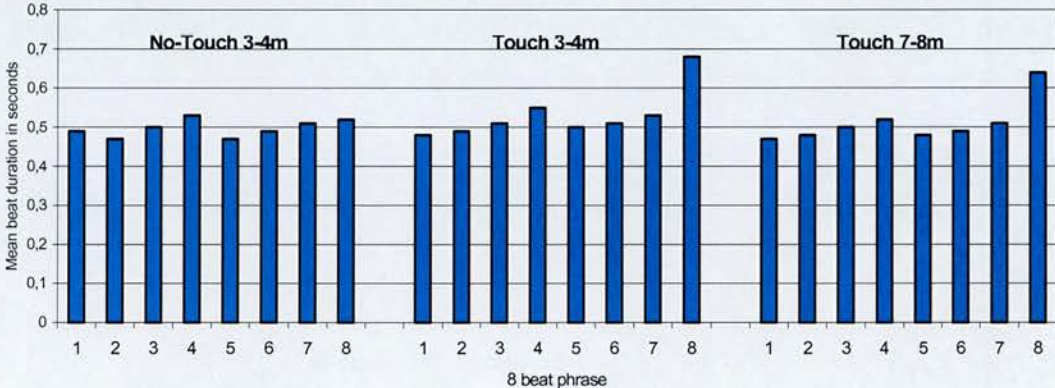


Figure 3.2 shows that all mothers increase in particular the length of the last beat of the phrase, i.e., the 8th beat. The ES2 and GS1 mothers also extend the duration of the 4th beat although not as strongly as the 8th beat, whereas the ES1 and GS2 mothers display a relatively even beat structure apart from the final one.

Figure 3.3 Mean duration of beat, expressed in seconds, by position in phrase, as a function of context and age, collapsed across mothers



As Figure 3.3 suggests, when the mothers sing to their infants in the touch context at both 3-4 months and 7-8 months, they tend to extend the duration of the last beat of the phrase, i.e., the 8th beat, with a slight tendency also to extend the 4th beat. However, when mothers sing to their 3-4 month-old infants in the no-touch context, this pattern is much weaker.

Table 3.7 Mean beat duration for each beat, type of beat, pair and phrase

Beat	Mean duration	Type of beat	Mean duration	Pair	Mean duration	Phrase	Mean duration
1 st	0.45s	Downbeat	0.48s	1 st (1 st + 2 nd beats)	0.46s	1 st	0.47s
2 nd	0.45s	Upbeat	0.52s	2 nd (3 rd + 4 th beats)	0.50s	2 nd	0.48s
3 rd	0.47s			3 rd (5 th + 6 th beats)	0.47s	3 rd	0.47s
4 th	0.49s			4 th (7 th + 8 th beats)	0.55s	4 th	0.49s
5 th	0.45s						
6 th	0.46s						
7 th	0.51s						
8 th	0.60s						

A mixed four-way ANOVA was applied to examine the effects on the duration of the beat in relation to three within factors, i.e., phrase (x4 levels, i.e., the number of phrases in the song), pair (x4 levels, i.e., number of pairs in each 8-beat phrase), type of beat, i.e., upbeat/downbeat (x2 levels, i.e., contrast of stronger and weaker beat within each pair) and one between factor, i.e., condition (x3 levels, i.e., no-touch 3-4 months, touch 3-4 months, and touch 7-8 months). Table 3.6 presents the overall mean beat duration in relation to the within variables as well as each beat of the phrase. Analysis of variance was applied to the total dataset of song performances collapsed across mothers. The analysis was thus not by individual mothers but by song performances. If the assumption of sphericity was not satisfied, Greenhouse-Geisser p values were used.

First of all, there is no significant effect of phrase nor of condition. There is, however, a significant effect for the duration of pairs of beats, i.e., 1st-2nd beats versus 3rd-4th beats versus 5th-6th beats versus 7th-8th beats ($F(3, 87) = 13.98, p = .00001$). Bonferroni correction for multiple comparisons was used for post-hoc comparison yielding new threshold for significance of $p = .01$. Pairwise comparisons with 2-tailed (paired) t-tests reveal that the 2nd pair, i.e., the 3rd-4th beats, is significantly longer than both the 1st pair, i.e., 1st-2nd beats, ($t = 4.41, df = 31, p = .00001$), and the 3rd pair, i.e., the 5th-6th beats, ($t = 3.23, df = 31, p = .003$). Moreover, the 4th pair, i.e., the 7th-8th beats, is significantly longer than the 1st pair ($t = 5.52, df = 31, p = .00001$), the 2nd pair ($t = 3.55, df = 31, p = .001$), and also the 3rd pair ($t = 5.34, df = 31, p = .00001$). Therefore, when the mothers sing, they particularly extend the duration of the last pair of beats, i.e., the 7th and 8th beats, explicitly marking the boundary between phrases. They also lengthen the duration of the 3rd and 4th beats of the phrase of the song, marking the midpoint of the phrase or boundary within phrases.

Regarding the duration of the type of beat, i.e., upbeat versus downbeat, there is a significant effect in respect of the difference between the downbeat (stronger beat), i.e., 1st, 3rd, 5th, and 7th beats, and the upbeat (weaker beat), i.e., 2nd, 4th, 6th, and 8th beats ($F(1, 29) = 9.09, p = .005$). Therefore, although in music downbeats usually represent the accented beats, mothers

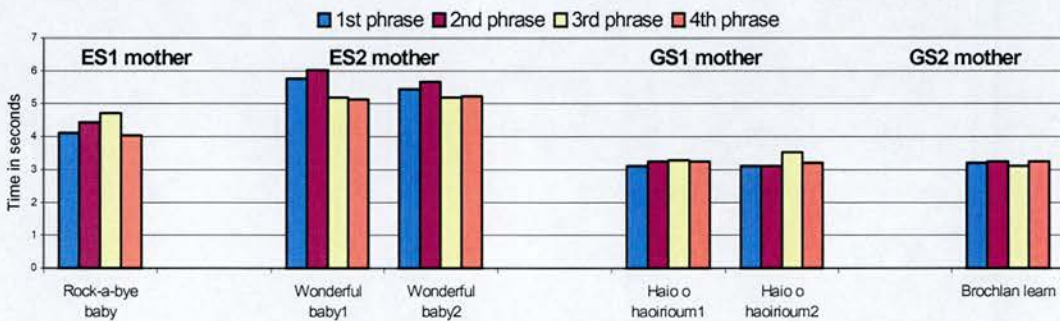
extend the duration of upbeats when singing to their infants. This is an important feature because, by marking the upbeats, mothers may be preparing their infants for the following stronger beat, similar to what the conductor of an orchestra does to signal that the main beat is next.

There is a significant interaction between pair and type of beat, i.e., downbeat/upbeat ($F(3, 87) = 4.87, p = .027$) which suggests that when a pair is longer, it is the upbeat in particular that is the reason for the extended pair. Thus the 4th and 8th beats might be the cause of the extended 2nd and 4th pairs. There is a trend towards a significant interaction between phrase and pair ($F(9, 261) = 2.59, p = .074$) which suggests that when mothers extend the duration of a pair, this also affects the duration of the phrase. Overall there is no effect of condition, suggesting that the mothers perform these variations when they sing to their infant irrespective of the presence or absence of physical contact and the infant's age.

3.2.2 The song structure: phrase duration and position in the song

This section explores the duration of mothers' phrases in different conditions, with particular attention being paid to the fact that the mothers might extend the duration of certain phrases of the songs in order to distinguish parts of the song. Figures 3.5 to 3.9 show the phrase durations for each song performance by every mother, as a function of context and age.

Figure 3.5 Phrase duration, expressed in seconds, as a function of mother and song during no-touch context at 3-4 months



When mothers sing during the no-touch context with their 3-4-month-old infants, the phrase duration ranges from 3.12s to 6.04s. The ES mothers sing longer phrases in comparison with the GS mothers. However, this is probably simply an artefact of the tempo of their songs, as ES mothers sing slower songs than GS mothers. Moreover, the phrase length of the GS

mothers appears relatively even, whereas the ES1 and ES2 mothers extend respectively the 3rd and 2nd phrases of the song.

Figure 3.6 Phrase duration, expressed in seconds, for the ES mothers, as a function of song during touch context at 3-4 months

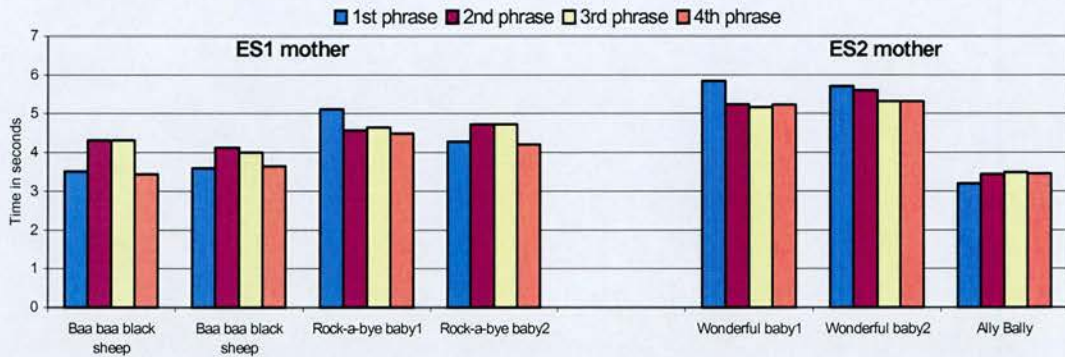
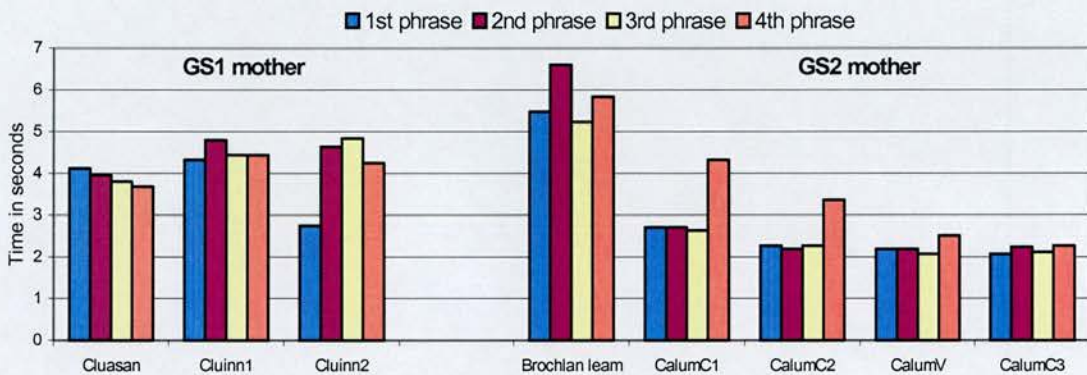


Figure 3.7 Phrase duration, expressed in seconds, for the GS mothers, as a function of song during touch context at 3-4 months



When the mothers sing to their 3-4 month-old infants, the duration of the phrases of the song ranges between 2.08s to 6.60s, which is similar to the no-touch context. Although the mothers display great variation when singing to their 3-4 month-old infants, it is interesting to note some patterns when they repeat the same song. For instance, when singing 'Baa baa black sheep' and 'Cluinn' respectively, the ES1 and GS1 mothers tend to lengthen the duration of the middle part, i.e., 2nd and 3rd phrases, of the song in both versions. On the other hand, when singing 'Wonderful baby' the ES2 mother appears to extend the duration of the first part, i.e., 1st and 2nd phrases, of the song in both versions. Finally, the GS2 mother sings the 'Calum' song consistently extending the duration of the 4th phrase, although in the final version there is no difference between phrase duration.

Figure 3.8 Phrase duration, expressed in seconds, for the ES mothers, as a function of song during touch context 7-8 months

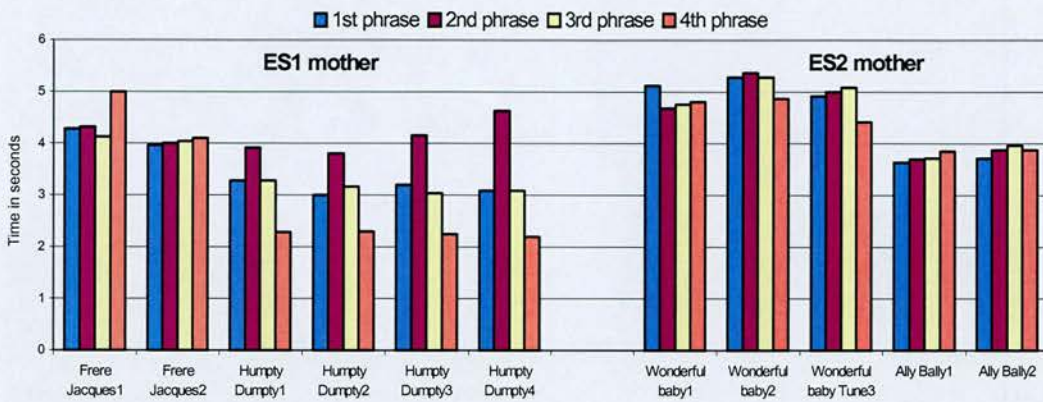
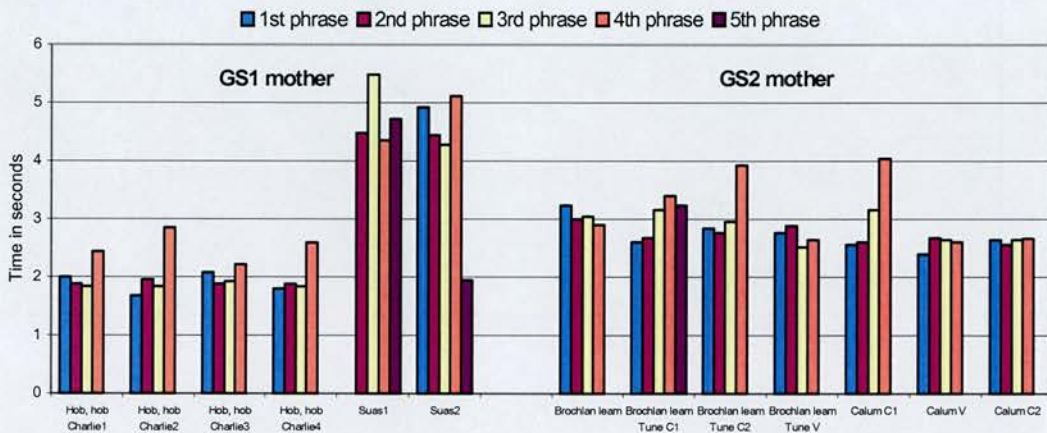


Figure 3.9 Phrase duration, expressed in seconds, for the GS mothers, as a function of song during touch context 7-8 months

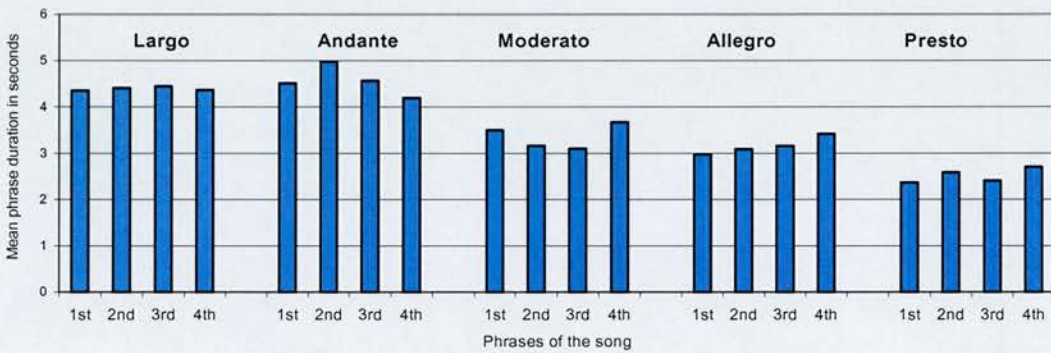


When singing to their 7-8 month-old infants during the touch context, the patterns of the ES mothers differ somewhat from those of the GS mothers. In particular, the ES1 mother usually stresses the 2nd phrase whereas the ES2 mother shows little difference in duration across phrases in either of her songs. The GS mothers' singing style is interesting not only because it is different from the ES mothers', but also because it has changed compared to their style in the songs they sang to their infants at 3-4 months. The GS mothers appear to play with the temporal structure of the song, introducing variations. For instance, during the song 'Hob, hob Charlie', in each version the GS1 mother adds an extra beat at the end of the last phrase, emphasising the final part of the song. Also, during the song 'Suas', the GS1 mother starts singing "senza misura", i.e., without temporal metre, or beat, and at the end she either repeats the last phrase or adds an extra bar. Similarly, at the end of the chorus of the 'Brochan leam' tune, the GS2 mother repeats the last phrase. It appears that both GS mothers

introduce temporal variations that modify the conventional structure of the songs and create new musical events. The GS mothers show a slight tendency to favour the lengthening of the 4th phrase. Overall, the duration of the phrases ranges from 1.88s to 5.48s, somewhat shorter than for the songs that were sung when the infants were 3-4 month-olds.

In section 3.2.1 an analysis of variance of the temporal structure of the song showed no significant effect of phrases of the song as a function of condition. In fact, as pointed out, phrase duration might be related to certain songs rather than others, i.e., repeated songs tend to be lengthened at the same phrase, because of its lyrics. Moreover, as suggested, it might be that only specific beats or pairs play a crucial role in determining the duration of the phrase. However, another factor that can affect phrase duration is the musical tempo of the song. Figure 3.10 shows the extent to which the mothers vary the duration of phrases in relation to the tempo of the song.

Figure 3.10 Overall mean duration of phrase, expressed in seconds, by position in song, as a function of musical tempo



If we consider the musical tempos of the songs, clearer patterns emerge. A two-way mixed ANOVA was applied to analyse the effects on phrase duration of one within-factor parameter, i.e., position of phrase in the song (x4 levels, i.e., the number of phrases in the song) and of one between-factor parameter, i.e., musical tempo of the songs (x5 levels, i.e., *largo*, *andante*, *moderato*, *allegro* and *presto*). Figure 3.10 shows the data used for this statistical analysis which refers to the mean phrase duration collapsed across mothers, contexts and the infant's age. If the assumption of sphericity was not satisfied, Greenhouse-Geisser p values were used.

Although there is no main significant effect of phrase, there is a significant effect of musical tempo ($F(4, 39) = 10.82, p = .00001$), suggesting that the musical tempo of the song has an

effect on the phrase duration. Moreover, there is a significant interaction between phrase duration and the musical tempo of the songs ($F(12, 117) = 3.98, p = .00001$). This indicates the way in which mothers vary the duration of their phrases according to their position in the songs across tempos. Because when the mothers sing faster tempos they appear to extend the duration of the last phrase of the song, a pairwise comparison was done on the *moderato*, *allegro* and *presto* tempo songs combined. Bonferroni correction for multiple comparisons was used for post-hoc comparison and the threshold for significance is $p = .016$. The mothers extend significantly the duration of the 4th phrase compared to the 1st and 3rd phrases but not the 2nd one (t-tests 2-tailed (paired) analysis, 4th phrase vs 1st phrase, $t = 3.64, df = 24, p = .001$, 4th phrase vs 2nd phrase, $t = 2.26, df = 24, p = ns$, and 4th phrase vs 3rd phrase, $t = 2.58, df = 24, p = .016$). During *andante* tempo mothers appear to extend the duration of the 2nd phrase, whereas during *largo* tempo they do not show any variation in phrase duration.

3.3 Discussion and conclusion regarding temporal structure of the mothers' songs

This chapter focused on the musical tempo and temporal structure of the songs mothers sing when in interaction with their infants. Mothers chose to sing principally playsongs (nursery rhymes and infant songs), but rarely lullabies. This is in line with work by Trehub and colleagues (1997) who observed that when infants are awake, adults are more likely to sing playsongs than lullabies. The mothers' choices of songs reflect their personal and cultural background. In fact, the GS mothers sing mostly Gaelic songs, emphasising their linguistic heritage. The songs they choose not only are sung in Gaelic but also are part of the musical tradition. This is particularly interesting because the function of playsongs is not only for entertainment, they also have a didactic role. As several authors have noted, playsongs help the transmission of information across generations (Cong-Huyen-Ton-Nu, 1979), and serve as a 'vehicle of enculturation' (Trehub & Schellenberg, 1995). This is also emphasised by the repetition of the songs in the same context and sometimes also across contexts. Repetition, which is typical in oral poetry and songs (Lomax Hawes, 1974), has a didactic value enabling the memorisation and acquisition of musical phrases, rhythms and melody, as well as words and knowledge (Sakata, 1987).

Another interesting feature of the lyrics of the songs is that the ES2 and GS2 mothers personalise the playsongs by including their infants' names and narrating family events within the texts of the songs. One possible function of using the infant's own name in the

song might be to attract her infant's attention, thereby fulfilling a vocative function. In these cases the songs become an occasion for mothers to express their feelings and emotions to their infants and also represent a celebration of identification between the singer, i.e., the mother, and the audience, i.e., the infant, strengthening the relationship (Pantaleoni, 1985).

The temporal analysis of the songs shows that the mothers mainly sing in a range of tempos between *presto* and *largo*, i.e., with beat duration ranging between 270ms and 1180ms. Interestingly most of the songs occur at *allegro* (39.13%), and *andante* (34.78%) tempos (see Figure 3.1).

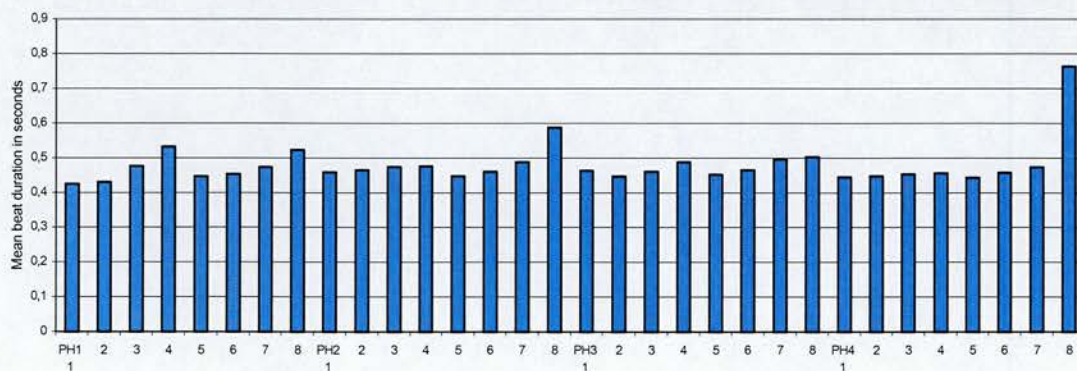
Moreover, with respect to condition, it emerges again that *andante* and *allegro* are used in every context and at all ages. As far as context is concerned, in the no-touch context the ES mothers sing songs at medium to slow tempo, probably in an attempt to comfort their infants, whereas the GS mothers produce fast pace songs, possibly to create a playful and joyful interaction in this unusual context. Interestingly, in the absence of physical contact, mothers do not sing at a *presto* tempo, which they may consider inappropriate for this context. On the other hand, during the touch context at 3-4 months each mother sings songs at both slow and fast tempos. It is likely that the function of fast songs is to arouse and stimulate infants, whereas the function of the slow pace songs is to calm and comfort infants. Thus, by singing both slow and fast songs, mothers may be helping their infants to maintain a homeostatic level of arousal. Although every mother repeats the same song at least once, usually singing it at the same tempo, the GS2 mother sings differently. In fact, she sings one version at a faster pace, possibly to increase the tension in the musical interaction for playful purposes. Interestingly, in the touch context at 7-8 months, mothers still sing at both slow and fast tempos, suggesting that they still aim to maintain their infants' homeostatic state. However, during the touch context at 7-8 months, *largo* and *presto* tempos are used less than in the touch context at 3-4 months, but now they sing at a *moderato* tempo which was not used before. Moreover, the GS mothers again slightly change the tempo of the songs with which infants are familiar, perhaps creating musical tension for playful purposes or to stimulate and maintain their infants' attention. It is interesting to note that during the three conditions, the amount of songs sung at *andante* tempo is always the same. Overall mothers are especially prone to singing songs at *andante* and *allegro* tempos, although to some extent they also use other tempos. However, it is interesting to note that in both touch contexts, often the same mothers sang songs at both fast and slow tempos. This might be a strategy on their part to avoid overstimulation of their infants and to maintain their homeostatic state.

Therefore the findings partially support the prediction based on Fraisse's theory (1964, 1982) in which he suggested that we have internal clocks that regulate the pace of perceived and produced information at about 500 to 700ms, i.e., *moderato* and *andante* respectively. Such a rate also corresponds to the spontaneous tempo, e.g., the natural tempo of the tapping finger, and the preferred tempo, i.e., the pace of the succession of stimuli which appears the most natural, neither too fast nor too slow. In fact, the fact that mothers sang so frequently at an *andante* tempo suggests that they have some preference for this tempo. However, the wide range of musical tempos used by the mothers when singing to their infants can be explained in two ways. The use of faster tempos, i.e., *presto* and *allegro*, might be used by the mothers in order to attract their infants' attention. In fact, according to the Dynamic Attending theory by Mary Jones (1987), the Reference Period, i.e., the oscillator that guides attention, slows with age in relation to biological cycles. Consequently young infants are more sensitive to faster tempos, in contrast to adults who react to slower tempos. Secondly, mothers might use slower tempos in order to maintain their infants' homeostatic state, thus avoiding overstimulation. According to Korner (1979) mutuality of interaction is possible when the mother is able to attune with the infant, modifying her responses and helping the infant to reach a homeostatic level. Similarly Stern et al. (1977) noted that the mother has to keep modifying her tempo and kind of activity in response to the continuous fluctuations and changes in the infants' state and needs. Thus the mothers' intuitive parenting might guide them to offer varying and appropriate musical stimulation as a function of their infants' state.

When I analysed the duration and distribution of the beats of the mothers' songs, I observed some regularities which might help infants to segment the musical information into temporal units. In particular, and contrary to my expectation, I found that mothers significantly extend the duration of the upbeat rather than the downbeat. This is interesting because outside mother-infant interaction in the alternation of stronger and weaker beats, it is usually the downbeat that is the stronger compared to the weaker upbeat. In fact, according to Radocy and Boyle (1997) the stronger beats are the first beats of each bar, i.e., the 1st and 5th beats, when there are 4 beats in the bar. Thus, the mother's tendency to emphasise the upbeat could be her way of signalling to her infant that the downbeat beat is about to follow. This strategy is not only used by the mothers, but also occurs in professional musical performances where the conductor emphasises the upbeat to the musicians so they can play on the downbeat. This could have biased the orchestra conductor who tapped the mothers' beat in the study, but, because of the high inter-rater reliability with the tapping performed by another musician (the drummer) with a very different background, this should not in fact have affected the

assessment of beat length. Another important characteristic of the mothers' beat is that duration varies significantly across pairs of beats. In particular, the 2nd and 4th pairs are significantly longer than the others. This means that the mother stresses the metric structure of the whole within the phrases of the song as well as between the phrases of the song. Trainor et al. (1997) found that when mothers sing playsongs to their 4- and 7-month-old infants they increase the duration of the final syllable plus the pause between phrases. These authors found that this holds only when singing in the infant-present context and during playsongs, but not within lullabies. Although this study does not assess the same issues as that of Trainor et al., it is still interesting to note that my findings, based on the beat duration, also show that the mothers increase the duration of the final part of the phrase, i.e., the 8th beat. Moreover, mothers create a pause in the middle of the phrase by lengthening the 3rd and 4th beats. The significant interaction between pair and upbeat/downbeat might indicate that when there is an extension of the pair duration this is due to the upbeat, i.e., the 4th and the 8th beats. Thus mothers mark the boundaries between phrases and also within phrases independently of physical contact or the infant's age. Finally, there is a trend towards significance in the interaction between pair and phrase which suggests that the mothers tend to emphasise some parts of the song, creating a new hierarchical level in the musical event. Overall, the mothers appear to mark boundaries at different levels and segment the song into small units, perhaps in order to help their infants process the musical information. Interestingly, the mothers' emphasise of the hierarchical structure of the song occurs quite consistently across contexts and the infant's age. This suggests that mothers do not need to touch their infants, and that infants do not need to be at a specific age in order to stress the temporal structure of the song. Figure 3.11 illustrates these findings by presenting a summary of the average temporal structure of the songs across all mothers and all conditions.

Figure 3.11 Average temporal structure of songs with 4 phrases of 8 beats



Another important aspect of the temporal structure of the songs is characterised by the phrase. In fact, the phrase represents another level of temporal unit, and the prolongation of the phrases might assist in the perception of the song into smaller units (Clark & Krumhansl, 1990; Krumhansl & Jusczyk, 1990; Lerdahl & Jackendoff, 1983; Palmer & Krumhansl, 1987a,b). The duration of the mothers' phrases range between 1.68s and 6.60s, which is similar to the range of phrases in prelinguistic vocalisations, poetry, and adult speech (Krumhansl, 1992; Lynch et al., 1995). It is also similar to what has been defined by Fraisse (1964) to be the 'psychological present' which corresponds to a temporal window of around 5s. The 'psychological present' is the temporal unit that makes it possible to link together clauses and phrases into a whole (Fraisse, 1982; Parncutt, 1994). Therefore, the phrases of the song represent another level of temporal organisation which may be discriminated as such by infants. Although there is no a significant main effect of the duration of the phrases of the song in relation to condition and musical tempo, there is a significant interaction between phrase duration and the musical tempo of the songs. Thus mothers vary the duration of the phrases of the song according to the musical tempo. For instance, when they sing songs at either *moderato*, *allegro* or *presto* tempos, mothers significantly extend the duration of the 4th phrase compared to the 1st and the 3rd phrases but not the 2nd one. During *andante* tempo they seem to extend the 2nd phrase of the song, whereas during *largo* tempo mothers sing every phrase very regularly without variation. Although this effect might be provoked by a few beats which magnify the overall effect of the phrase, it is still important to note that the mothers structure songs differently according to their musical tempo.

Lerdahl and Jackendoff (1983) speculated that a hierarchical structure exists in which speech and music are organised into units that vary in duration. However, they did not provide any evidence to support their claim. In this chapter, I have provided evidence that mothers emphasise the hierarchical structure of songs, extending the duration of the 8th beat primarily, and the 4th beat to a lesser extent, thus segmenting the musical event into phrases and into smaller units within phrases. Furthermore, by extending the duration of the 4th and 8th beats in the 2nd and 4th phrases, mothers provide another level of segmentation of the song. Later, in Chapter 5, I will examine whether infants are sensitive to these boundaries marked by their mothers.

On the basis of Trehub's and Schellenberg's (1995) claim that towards the end of the first year of the infant's life mothers change their style of singing, I predicted that mothers would change their singing style when singing to their 7-8 month-old infants compared to 3-4

month-olds. However, only the GS mothers displayed this pattern. They added a phrase, a beat, or a bar at the end of the song, or they sang the first part of the song without tempo (*senza misura*). The reason why only the Gaelic mothers performed these temporal variations may be due to the fact that they are more familiar with musical variation, and that creativity is very much more part of their culture (viz. the Mod and all the musical competitions in the Gaelic community), than is the case for the ES mothers.

In this chapter, it was first hypothesised that mothers would sing songs regularly around 500-700ms, i.e., at respectively *moderato* and *andante* tempos. Although mothers sang a greater variety of tempos ranging from *largo* to *presto*, it emerged that *andante* and *allegro* are the most common tempos sung by the mothers. Therefore my prediction is partially confirmed. Secondly, it was predicted that the mothers would emphasise the hierarchical structure of the songs, and indeed they were found to do so irrespective of the presence or absence of physical contact or the infant's age. Thirdly, it was expected that they would stress in particular the 1st and 5th beats of an 8-beat phrase, but they did not show this pattern. Rather, they extended the duration of the upbeats. Fourthly, it was hypothesised that they would extend the duration of the 8th beat of the phrase, marking the boundary between phrases. My findings show that indeed mothers not only extend the duration of the 8th beat but also of the 4th beat, suggesting that they create another level of segmentation in the middle of the phrase. Fifthly, it was expected that the phrasing structure of the songs would be emphasised, but no specific prediction was made. Although mothers displayed great variation of phrase duration in relation to context and age, there is no significant effect of phrase. However, there is a significant interaction of phrase duration and musical tempo suggesting that mothers vary the duration of the phrases of the song in relation to the tempo of the songs. Finally, it was hypothesised that mothers would modify the structure of the songs when singing to their 7-8 month-old infants. Only the GS mothers showed this pattern.

3.4 Summary of the chapter

This chapter has shown that when mothers sing to their infants they use a wide range of tempos which go well beyond the tempos which correspond to the 'indifferent interval' or optimal zone suggested by Fraisse (1964, 1982). In fact, it was demonstrated that mothers sing songs at both fast and slow tempos within the same context. This suggests that they want both to arouse their infants but at the same time avoid over-stimulation and maintain their homeostatic state. In particular, as part of their intuitive parenting, mothers seem to use faster tempos in order to capture their infants' attention.

The analysis of the temporal structure of the songs revealed that mothers emphasise the hierarchical structure of the song independently of the context and age. In fact, they significantly extend the duration of the upbeats in general and the 4th and 8th beats of the phrases in particular. A significant interaction between pair and phrase suggests another level of song segmentation. This is interesting because it might allow infants to segment the musical structure into smaller units and thus might facilitate their processing of the musical information. From this perspective, the duration of the phrase is the result of the extension or reduction of the duration of a few beats within it. Therefore, the perception of phrases might be weaker than the perception of small units within phrases. However, I found a significant interaction of phrase duration in relation to musical tempo, suggesting that mothers maintain predictability of phrasing structure according to the tempo of the song. Thus, musical interaction is a complex phenomenon which occurs at different levels, and which is modified by mothers in order to regulate their infants' needs and states.

The next chapter examines mothers' and infants' physical and communicative-affective reactions in musical interactions in which mothers sing songs. In particular, the partners' level of activity, cyclical behaviours, and communicative-affective behaviours, as well as the infants' emotional states and degree of engagement are analysed. Finally, the partners' participation is related to the phrasing structure of the song in order to understand whether the temporal structure of the song affects physical and communicative-affective reactions in mother-infant interaction.

CHAPTER FOUR

Mothers' and Infants' Physical and Communicative-Affective Behaviours in Interactions with Songs

This chapter examines how mothers and infants participate in interactions in which the mother sings songs, focusing on the partners': a) physical behaviours, which include level of activity and cyclical actions (section 4.1); b) communicative-affective behaviours as well as the infants' emotional states and degree of engagement (section 4.2.); and, c) how these relate to the phrasing structure of the song (section 4.3.). In particular, in sections 4.1 and 4.2 I include qualitative data which will be used in the final chapter to generate suggestions for follow-up experiments. Moreover, the same analysis of these two sections will be applied in Chapter 6 to interactions with taped music.

4.1 How mother and infant participate in interactions with songs

When listening to a piece of music or a song, the listener's response can be 'emotional' (conveying either an excited or calm state), 'behavioural' (making the listener dance, tap his foot, or clap his hands), and finally 'physiological' (causing a change in heart rate and muscular tension) (Handel, 1989). But what happens when the listener is a young infant?

Infants' physical and behavioural responses to playsongs have been acknowledged by several authors (Holahan, 1987; Kelley & Sutton-Smith, 1987; Papousek & Papousek, 1981; Trehub, 1993; Trehub & Henderson; 1994, Trevarthen 2000). In the first year of life, infants display interest and enjoyment in the presence of music. They smile, vocalise and engage in a rudimentary dance. However, very few empirical studies have been carried out that go beyond mere anecdotal observation of the infant's behavioural activity when exposed to songs and music. In one exploratory study, Moog (1976) observed that at 4 to 6 months of age infants are more likely to move their whole body, but towards the end of the first year they are more likely to move individual body parts. Not only do infants move to music, but they also organise these behaviours into cyclical patterns. In one previous study comparing lullabies and playsongs, Rock and colleagues (1999) explored the rhythmic motor responses of a group of 6-month-old infants. The rhythmic behaviours considered were: leg kicking, body bouncing, arm banging and head bobbing. The most common rhythms were leg

kicking, head bobbing and body bouncing which the infants performed similarly in both the lullaby and playsong conditions. However, contrary to the authors' predictions, the infants showed a trend towards producing more rhythmic behaviours when listening to lullabies compared to playsongs. The authors explain this by the fact that playsongs have the function of capturing the infant's attention and, when this happens, their response is to stop their ongoing activity.

These studies have focused on the behavioural activity of infants around 6 months of age onwards. None has explored interactions in the context of songs at 3 months nor looked at the role of touch. What happens with younger infants at 3-4 months of age? More generally, what is the infants' level of activity when mothers sing to them at different ages (i.e. 3-4 months versus 7-8 months) and in different contexts, i.e., during a no-touch compared to a touch context?

Cyclical actions represent the rhythmical component of movements. How much cyclical activity do infants display? And which kind of cycles do infants perform? Does this change with age? And, what about the mothers? What do their levels of activity and rhythmical behaviours look like when they sing to their infants at different ages and in different contexts? Which kind of cycles do they display the most? Are their level of activity and cyclical behaviours related to the musical tempo of the songs?

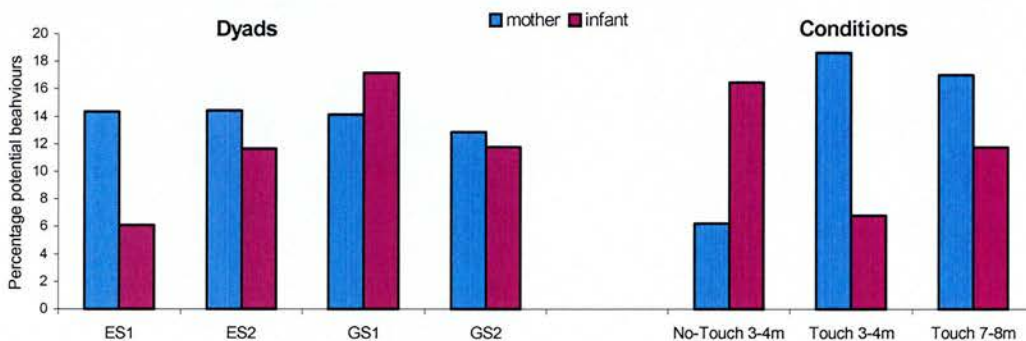
It is hypothesised that 3-4-month-old infants will show a lower level of activity in the no-touch context compared to the touch context. Also, at 7-8 months of age infants are expected to produce more actions compared to when they were younger. At 3-4 months of age infants are predicted to perform rhythmical patterns in the presence of songs. Moreover, I hypothesise that their rhythmical activity will increase at 7-8 months. The kind of cycles infants perform will, I predict, be mostly leg kicking, head bobbing and body bouncing, in line with suggestions by Rock et al. (1999). According to Moog (1976) we should also expect cyclical behaviours to be spread through the whole body when the infant is around 3-4 months, but when older the infant should show more actions involving individual body parts. I predict that the mothers' level of activity and rhythmical behaviours will not vary in relation to the age of the infant or differences in physical contact. In fact, I expect that the mothers will show a moderate level of activity in both contexts and at both infant ages. Also it is anticipated that they will produce a low level of cyclical actions involving contact with the infant compared to actions that involve only their own body. No prediction is made with

respect to the mother's and infant's level of activity and cyclical behaviours in relation to the musical tempo of the songs. The main concern of the mother will, I believe, be to avoid over-stimulation of her infant in order to ensure his homeostatic state.

The above hypotheses were tested on the base of the dataset of interactions involving songs in contexts where mothers could touch their infants were contrasted at 2 ages: 3-4 months and 7-8 months. At 3-4 months two contexts were compared: no-touch versus touch. The dataset is presented in Chapter 3 section 3.1.2. I measured the level of physical activity and rhythmical behaviours performed by the mother and the infant in different conditions. In Chapter 2, section 2.3.1.1, the procedure to determine the partners' level of activity and cyclical actions was explained. In particular, level of activity is measured as a percentage of the potential amount of activity, because each partner could move simultaneously different parts of the body. Amount of cyclical action, by contrast, is measured as a percentage of the total amount of the actual activity.

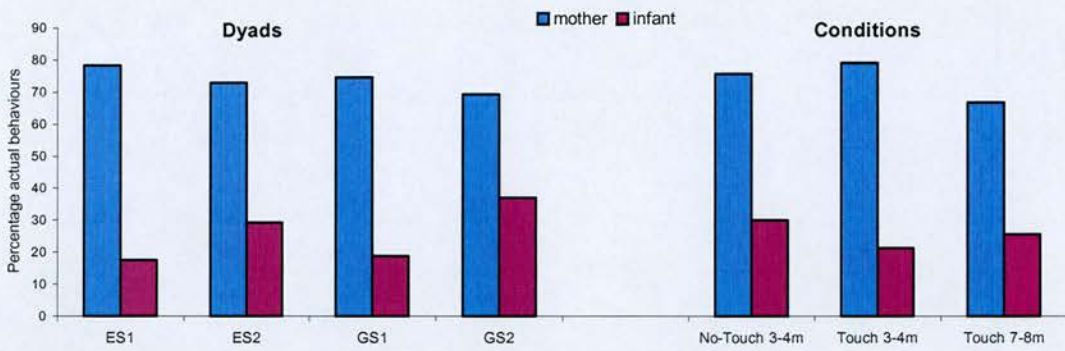
Figures 4.1, 4.2, and 4.3 show the mothers' and the infants' levels of activity and cyclical behaviours, as a function of dyad, context, age and musical tempo of the song.

Figure 4.1 Mothers' and infants' overall level of activity expressed as a percentage of their potential amount of activity, as a function of dyad, context and age



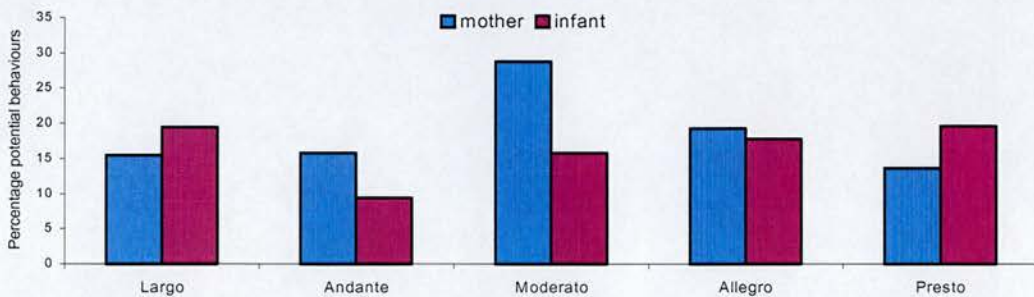
Mothers and infants display similar levels of activity in Figure 4.1. However, there are some small differences. Although mothers are generally more active than their infants, especially the ES1 mother, in the case of the GS1 dyad the infant is more active than the mother. In the no-touch context at 3-4 months, mothers' level of activity is smaller compared to the touch context. On the other hand, infants produce a higher level of activity in the no-touch context at 3-4 months compared to the touch context and are more active than their mothers. At 7-8 months infants increase their level of activity compared to 3-4 months.

Figure 4.2 Mothers' and infants' overall amount of cyclical behaviours expressed as a percentage of the total amount of their actual activity, as a function of dyad, context and age



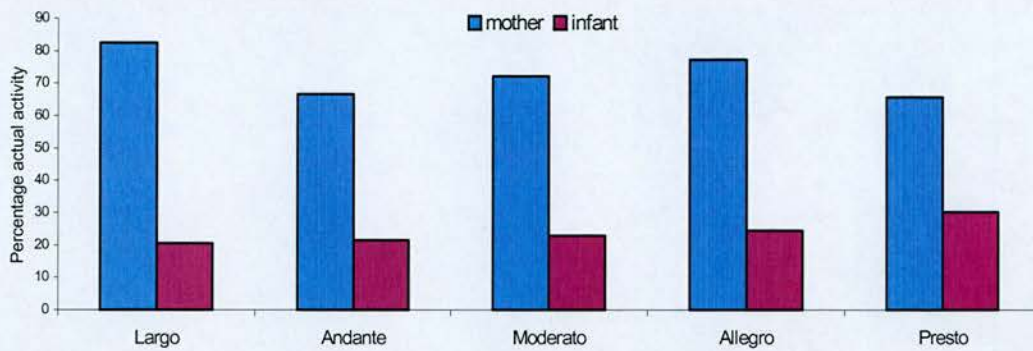
When the partners' amount of cyclical behaviours is considered, it is interesting to observe the considerable differences between mothers and infants. In fact, the mothers produce around 70% of their behaviours in cycles, whereas for infants an average of only 25% of their overall actions are cyclical. Overall the percentage of the mothers' cyclical behaviours is high in each condition, although at 7-8 months mothers produce a slightly lower percentage of cyclical patterns compared to 3-4 months. In general, infants produce a smaller percentage of cyclical behaviours compared to their mothers. At 3-4 months, infants produce a lower percentage of cyclical actions in the touch context compared to the no-touch context. Interestingly infants do not show an increase of cyclical behaviours at 7-8 months compared to 3-4 months.

Figure 4.3 Mothers' and infants' overall level of activity expressed as a percentage of their potential amount of activity, as a function of musical tempo



When we consider the musical tempos of the songs, it is interesting to observe that the partners of the dyad produce somewhat different levels of activity. For instance, as shown in Figure 4.3, during *moderato* tempos, mothers produce a higher level of activity compared to the other tempos, especially *presto* where they move the least. On the other hand, infants perform a smaller percentage of behaviours during *andante* tempos compared to the others.

Figure 4.4 Mothers' and infants' overall amount of cyclical behaviours expressed as a percentage of the total amount of their actual activity, as a function of musical tempo

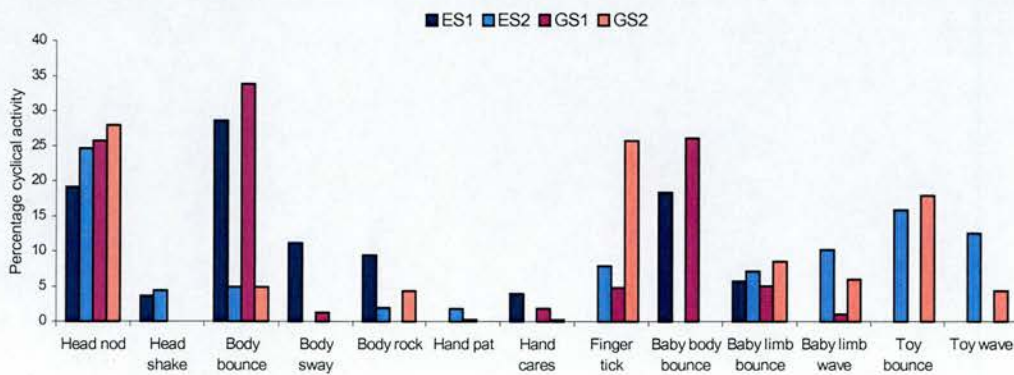


Overall, mothers' and infants' percentage of cyclical activity does not appear to be particularly affected by the musical tempo of the songs. However, mothers appear to produce their highest percentages of cyclical behaviours during *largo* and *allegro* tempos, whereas infants display slightly more cyclical behaviours with *presto* tempo.

4.1.1 Types of cyclical behaviours produced by mothers and infants

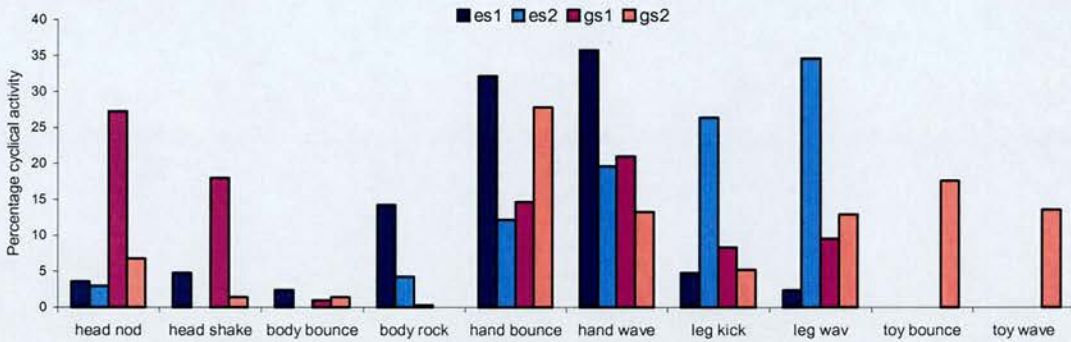
This section examines the types of cyclical patterns that mothers and infants mostly perform during interactions involving songs. Figures 4.5 to 4.10 display the different types of cyclical behaviours produced by mothers and infants, expressed as a percentage of their overall cyclical participation. Because mothers perform a large variety of cycles which involve different parts of the body and which sometimes involve contact with their infants, I only consider here the most common cycles across mothers. Such a restriction was unnecessary for infants because the variety of cycles they perform is smaller.

Figure 4.5 Mothers' types of cyclical behaviours, as a percentage of total amount of cyclical behaviours, as a function of mother, collapsed across conditions



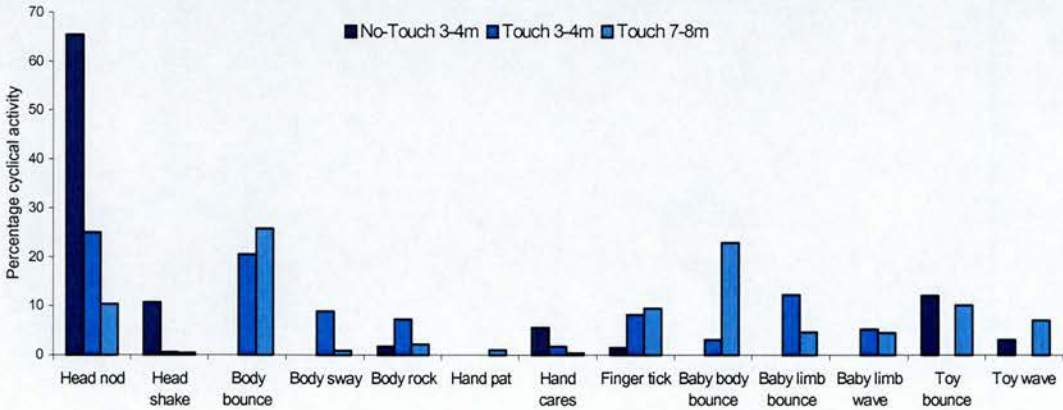
As Figure 4.5 shows, when singing to their infants mothers display a wide variety of cyclical patterns comprising movements of their head, body, hands and fingers, actions that involve contact with the infant's body and limbs, and also actions that involve moving the toy rhythmically. However, there are some cycles that are more common than others. For instance, all mothers produce a lot of head nodding. They also all display body bouncing and bouncing the baby's limbs, which are movements that have vertical orientation.

Figure 4.6 Infants' types of cyclical behaviours, as a percentage of total amount of cyclical behaviours, as a function of infant, collapsed across conditions



In Figure 4.6 it appears that infants' patterns differ substantially from their mothers' in that infants show less variety and mainly display hand bouncing and hand waving. All infants perform hand bouncing, hand waving, leg kicking and leg waving, as well as head nodding. By contrast, head shaking, body cycles, and toy cycles are more specific to individual infants.

Figure 4.7 Mothers' types of cyclical behaviours, as a percentage of total amount of cyclical behaviours, as a function of context and age



As Figure 4.7 shows, during the no-touch context at 3-4 months, mothers mainly produce head nodding and some head shaking, hand and toy cycles. In the touch context at 3-4 months mothers often move their head and body in cycles, and move more frequently their infant's limbs than body in cycles. However, at 7-8 months mothers move less often their head and body in cycles. Rather, they increase toy cycles and cycles in contact with the baby's body compared to the 3-4 months context.

Figure 4.8 Infants' types of cyclical behaviours, as a percentage of total amount of cyclical behaviours, as a function of context and age

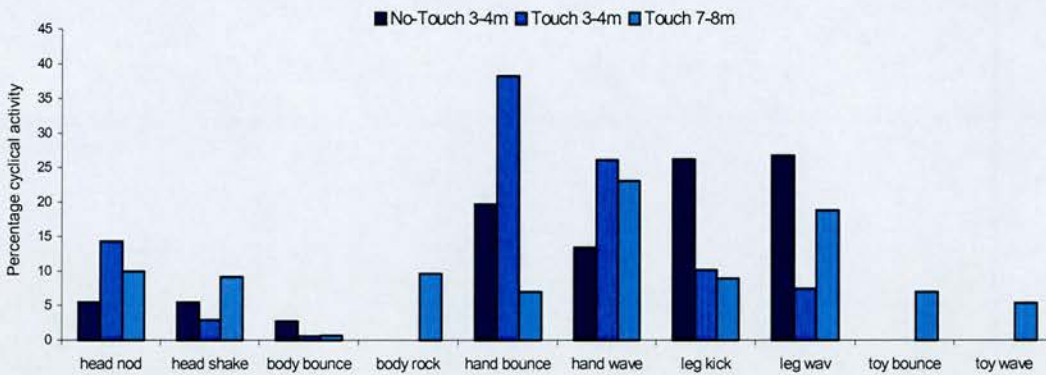
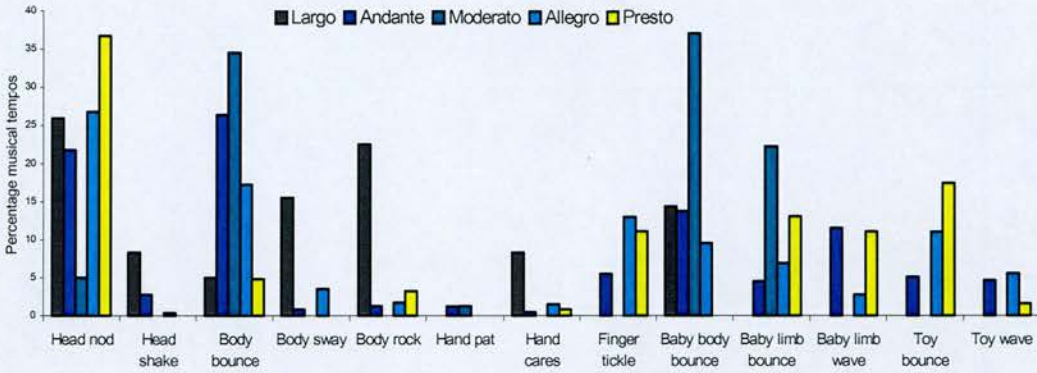


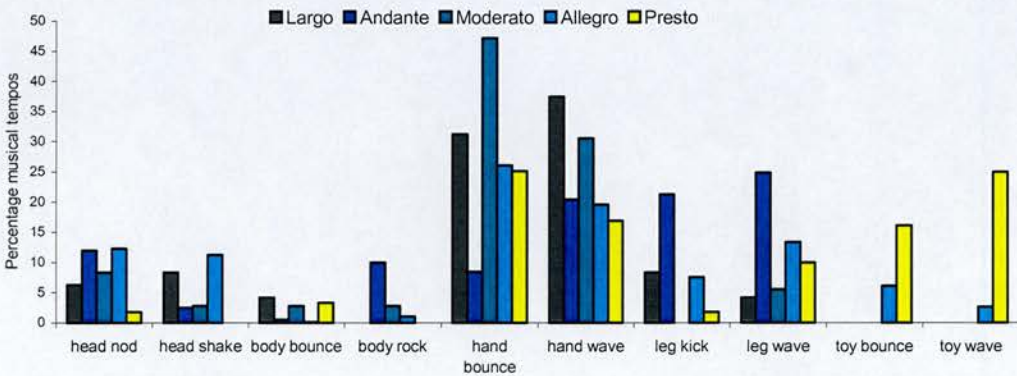
Figure 4.8 illustrates that during the no-touch context at 3-4 months infants appear to produce a variety of cycles which involves mostly leg kicking and leg waving. They also display some hand bouncing and waving, and to a lesser degree head and body cycles. In the touch context at 3-4 months, infants increase their hand bouncing, waving, and head nodding, but produce less leg cycles compared to the no-touch context. At 7-8 months infants produce cycles that are not found at the younger age level, such as body rocking, toy bouncing and toy waving. Moreover, they increase the percentage of head shaking and leg waving compared to the 3-4 months context.

Figure 4.9 Mothers' types of cyclical behaviours, as a percentage of total amount of cyclical behaviours, as a function of the musical tempo



Although mothers sing at different tempos, they produce head nodding and body bouncing with any musical tempo, and bouncing baby's body and limbs across most of the musical tempos (see Figure 4.9). However, cycles like body swaying, rocking, and hand caressing seem to occur more frequently during *largo* tempo, whereas finger tickling and toy bouncing happen more often during *allegro* and *presto* tempos. Although cycles in contact with the infant's body and limbs occur with a variety of tempos, they are more frequent during *moderato* tempo.

Figure 4.10 Infants' types of cyclical behaviours, as a percentage of total amount of cyclical behaviours, as a function of musical tempo



Hand bouncing, hand waving, leg waving, and less often head nodding are cycles which infants perform during all musical tempos. However, during *largo* and *moderato* tempos infants produce a larger percentage of hand cycles compared to during the other tempos. On the other hand, during *andante* tempo infants display more frequently leg kicking, leg waving, and body rocking. At *presto* tempo infants produce several toy cycles. Finally, at

allegro tempo infants produce a variety of cycles which involve mostly their hand, leg, and head but few toy cycles.

4.1.2 Discussion and conclusions regarding infants' and mothers' physical behaviours

When the mothers' physical behaviours are considered in interaction with songs their level of activity and amount of cyclical behaviours were predicted not to change in relation to context or age, and no specific prediction was made regarding musical tempo of the songs. Although mothers were expected to maintain a moderate level of activity, mothers tended to change their amount of behaviours in relation to context. They might do so in order to adjust to the infant's level of activity. During the no-touch context at 3-4 months mothers move very little compared to the touch context. It could be that mothers find it difficult to participate and respond to music when they are in interaction with their infants but cannot physically share with them the musical experience. Age does not appear to have much effect on mothers' level of activity although they seem to reduce their activity slightly at 7-8 months. With respect to the musical tempo of the songs, mothers are particularly active during *moderato* but display the least activity during the *presto* tempo. This is interesting because although at faster tempos mothers might be prompted to produce more actions, when the tempo of the music is very fast they seem to produce less activity. It could be that they are concerned about over-stimulating their infants and hence restrain their level of activity.

Mothers' cyclical activity turned out to be extremely rich. Such rhythmical behaviours in mothers are important because they have been suggested by Tronick et al. (1977, 1979) to constitute a special means of mutual regulation within mother-infant interaction. Although mothers were expected to produce a moderate amount of cycles in every condition, in fact they turned out to produce constantly a high percentage of cyclical behaviours. Only in the 7-8 months context did mothers decrease somewhat their cyclical participation compared to when the infant was younger. This could be due to the fact that by this time the terms of the interaction have changed into a more mutual exchange with the infant producing more vocalisations, thereby causing the mother to decrease rhythmical actions. So, in early interaction cyclical behaviours might be an important feature which allows mothers to capture their infants' attention and interlock with them. However, later when vocalisation becomes more prominent, the cyclical activity in the interaction may become less necessary.

Although no prediction was made regarding the relation between musical tempo and mothers' cyclical behaviours, I found that mothers produced the highest level of cyclical activity during the *largo* and *allegro* tempos. Thus it seems that mothers are extremely cyclical in these antipodal musical tempos, perhaps in order to keep their infants' attention. On the other hand, during *andante* and *presto* tempos mothers move less often in cycles compared to the other tempos. This is interesting because the *andante* and *allegro* tempos are the most common tempos performed by the mothers when singing to their infants (see Chapter 3, Figure 3.1). In fact, because mothers behave differently during these two tempos, they may be using them in order to counterbalance their level of cyclical participation.

With respect to the mothers' types of cyclical behaviours across conditions, a low level of cyclical actions was expected in contact with the infant compared to cyclical behaviours that involve only the mothers' own body. Overall it emerged that mothers produce a wide variety of cycles and, as predicted, most of them involved their own head and body. According to Papousek and Papousek (1981), mothers have a wide variety of rhythmical behaviours at their disposal to modulate their infants' physical and emotional states in order to bring their infants to the right level of attention to process information, or to soothe them. My findings show that mothers produce a higher percentage of cycles with their own body rather than in contact with their infants. This holds especially in relation to context, and slightly less so in relation to age and musical tempo. In fact, during the no-touch context mothers produce a very high amount of head nodding compared to the touch context. This is perhaps because at 3-4 months of infant's age the interaction is characterised by gaze direction and face-to-face communication, and, in the absence of physical contact, mothers rely on visual stimuli. When mothers are allowed to touch their infants, they introduce some cycles in contact with the infant's limbs, but it is only when their infants are 7-8-month-old that mothers produce a high percentage of cycles in direct contact with the infant's body. At 3-4 months, this is not the case, thus running counter to my prediction. Moreover mothers reduce head nodding but produce several toy cycles suggesting that because the terms of interaction have changed, i.e., the interaction has become more triadic for the older infant, the visual rhythmical stimuli shift from the mother's face to the toy. With respect to musical tempo, mothers produce mostly head nodding and body bouncing, which are performed with all musical tempos. However, it is during the *moderato* tempo that mothers perform more cyclical behaviours in contact with the infant's body and limbs compared to their own body. In general mothers were found to produce mostly vertically-oriented cycles, like head nodding, body bouncing, finger tickling, which occur especially with moderate to fast

tempos. By contrast, during the *largo* tempo mothers produce mostly horizontally-oriented cycles. Interestingly, mothers seem to produce a larger range of cycles during the *allegro* and *andante* tempos compared to the other musical tempos. Perhaps these two tempos are more frequently used in mother-infant interaction because they involve a wide range of cycles that help mothers to modulate their infants' states.

With respect to the infant's level of activity, in the no-touch context at 3-4 months infants were predicted to produce a lower level of activity compared to the touch context. But at 7-8 months of age infants would increase their actions compared to 3-4 months. The findings suggest that infants' level of activity is related to both context and age and to some extent to musical tempo. In contrast to my prediction, infants display a higher level of activity in the no-touch compared to the touch context. It could be that, by their movements, infants try to prompt their mothers to touch them or they compensate for the lack of activity that otherwise would have normally been produced by physical contact with the mothers. However, as predicted, with age infants increase their amount of behaviours. In fact, at 7-8 months infants produce a higher level of activity compared to 3-4 months. Thus with age infants not only are stronger but also they are more dynamic during interactions in which their mothers are allowed to touch them while singing to them. Although infants display a similar level of activity across most tempos, they move very little during the *andante* tempo songs. Therefore mothers may sing at an *andante* tempo in order to avoid exciting their infants. As suggested by Stern et al. (1977), the mother has always to be ready to change the tempo of the interaction, the kind of behaviours or the intensity of activity, as a function of the states and needs of her infant.

In relation to the infants' amount of cyclical behaviours, it was expected that at 3-4 months infants would show rhythmical patterns and they would increase with age. No specific prediction was made in relation to musical tempo and infants' amount of cyclical behaviours. Infants produce cyclical behaviours at 3-4 months, as predicted, although a lower percentage than their mothers. In particular, during the no-touch context at 3-4 months infants move more often in cycles compared to the touch context at the same age. In contrast to my prediction, at 7-8 months infants do not show an increased level of cyclical behaviours compared to when they were younger. It might be that the decrease in the infants' engagement in the interaction (see section 4.2) at 7-8 months compared to 3-4 months reduces the extent to which they move rhythmically with the music. When we consider the

musical tempos of the songs, infants display a very similar level of cyclical behaviours across all musical tempos.

With respect to the types of cycles that infants perform during interaction with songs, infants were expected to perform mostly head nodding, body bouncing and leg kicking as found by Rock et al. (1999). Moreover, on the basis of Moog (1976) it was hypothesised that infants produce cycles which are spread through the whole body at 3-4 months of age, but at 7-8 months they would show cyclical behaviours specific to body parts. In relation to context and musical tempo there was no specific prediction regarding the kind of infants' cycles. As predicted, infants produce some head nodding, leg kicking and to a less extent body bouncing. However, I found that infants produce mostly hand bouncing and waving, and less often leg waving cycles. Therefore, the infants in this study display different cyclical actions and also a richer variety of cyclical behaviours compared to the Rock et al. work. A possible reason for this difference is that in the Rock and colleagues study, infants were placed on an infant treadmill, whereas in my study infants were either on the floor or on their mother's lap when physical contact was allowed. My results suggest that other factors also affect the infant's behaviour, including in particular the dynamics of the mother-infant interaction. On the other hand, at 7-8 months infants not only produce the same cycles as performed at 3-4 months, but they also produce cycles that they did not display previously. These include: toy bouncing, toy waving, and body rocking. Hence, as they get older, infants not only expand the range of their body's rhythmical behaviours, but they also move external objects in cycles. This is contrary to my hypothesis based on Moog's theory which suggested that towards the end of the first year of life infants perform cycles involving specific parts of the body, whereas at younger ages their cycles are spread across all parts of their body. Since my older group of infants was only 7-8 months of age, Moog's hypothesis may hold only towards 12 months. In other words, the findings reported here suggest that with age infants become increasingly capable of organising and co-ordinating actions with parts of the body that they could not easily control independently previously. Moreover, they produce slightly more cycles involving vertical movements at 3-4 months of age and more cycles involving horizontal movements at 7-8 months. With respect to musical tempo it emerged that infants produce hand cycles and leg waving, and occasionally head nodding which occur with every musical tempo. Overall the orientation of the infants' cycles does not appear to be related to any particular musical tempo. However, interestingly during *andante* and *allegro* tempos infants produce a variety of cycles which involve: hand, leg, head and slightly less often the body. It is possible that some of the rhythmical movements that infants produce when

interacting with their singing mothers may help to prepare the way for subsequent developments in the infants' motor system. In particular, it has been argued that the kicking movement of the infant's leg is a precursor of the future stepping movement, and hence of walking (Thelen, 1981). The bouncing movement of the hand is regarded as particularly important for its relation with the emergence of babbling (see Ejiri & Masataka, 2001; Locke et al., 1995). So early rhythmic movement may underpin subsequent developmental milestones.

In sum, I hypothesised that infants would show a lower level of activity during the no-touch context compared to the touch one. In fact, infants displayed the opposite pattern, producing more behaviours in the absence of physical contact. It was expected that infants would increase their level of activity at 7-8 months compared to 3-4 months and this turned out to be the case. Moreover, it was expected that infants would perform cyclical behaviours in interaction with songs at 3-4 months, a prediction that was confirmed by the results. However, although at 7-8 months of age infants were expected to produce more cyclical behaviours compared to 3-4 months, they do not show this pattern. On the basis of Rock et al. (1999) findings, infants were expected to produce mostly leg kicking, head nodding and body bouncing. Although to some extent they display these behavioural cycles, partially supporting my prediction, they perform mostly hand bouncing and waving with some leg cycles. Moreover, on the basis of Moog's (1976) observations infants were expected to produce at 3-4 months of age cyclical behaviours across the whole body and at 7-8 months cyclical behaviours more specific to particular body parts. However, contrary to my prediction, at 7-8 months infants not only were found to perform the same cyclical patterns as those exhibited at 3-4 months, but they also increased the range of cyclical activity. In fact, when they are older infants also produce body rocking and toy cycles. As far as musical tempo is concerned, no specific prediction was made in relation to infants' level of activity and cyclical behaviours. However, during the *andante* tempo infants produced the lowest level of activity compared to the other tempos. Although they perform similar amounts of cyclical behaviours across most tempos, infants seem to move slightly more often in cycles during the *presto* tempo. However, they appear to produce a wider variety of cycles during *andante* and *allegro* compared to the other tempos. But they do not seem to relate the orientation of cyclical behaviours to any specific tempo.

With respect to the mothers' physical behaviours, it was expected that the mothers' level of activity and cyclical behaviours would be moderate with no variation in relation to context or

age. However, contrary to my prediction, mothers vary their level of activity and cyclical behaviours in these different conditions. In fact, mothers display a lower level of activity in the no-touch context compared to the touch context. Although age does not seem to affect strongly the mothers' level of activity, when their infants are 7-8 months of age the mothers appear to be slightly less active. With respect to cyclical behaviours, in contrast with my prediction, mothers produce a high percentage of cyclical behaviours when singing in interaction with their infants. Although mothers seem to perform a similarly high percentage of cyclical behaviours across contexts, they show some differences when age is considered. In fact, at 7-8 months mothers seem to reduce the percentage of cyclical behaviours compared to 3-4 months, thus again refuting my prediction. In relation to the mothers' types of cycles, it was predicted that mothers would perform mostly cyclical behaviours with their own body rather than in contact with their infants. In fact, as predicted, mothers produce mostly head and body cycles compared to cyclical behaviours when in contact with their infants. However, this finding is especially true in relation to context but it is less strong when age is considered. In fact, at 7-8 months mothers increase the amount of cycles in contact with the infant's body compared to 3-4 months. No prediction was made with respect to the musical tempo of the song and the mothers' level of activity and cyclical behaviours. However, mothers were found to vary their level of activity in relation to the musical tempo. In particular they display a higher level of activity during the *moderato* tempo compared to the others. On the other hand, mothers do not seem to be particularly affected by musical tempo in relation to their cyclical behaviours, although they produce slightly more cyclical during the *largo* and *allegro* tempos. When musical tempo is considered in relation to the mothers' kind of cyclical behaviours, it emerges that mothers produce a high level of cycles in contact with the infant's body and limbs during the *moderato* tempo. In general, mothers appear to produce more vertically-oriented cycles during faster tempos and horizontally-oriented cycles during slower tempos.

4.2 Communicative-affective behaviours displayed by mothers and infants when mothers sing to their infants

Music is often considered to be a special medium for expressing emotions. Several authors have suggested that a close relation obtains between music and emotions (Meyer, 1956; Sloboda, 1991; Juslin & Sloboda, 2001). Rock et al. (1999) extended this concept, proposing that music might even be a more powerful medium than speech for communicating affect and emotion to infants. But how do mothers express their emotions when singing to their

infants during interaction animated by songs? And which emotions do infants display during interaction with songs?

Infant-directed songs are sung not only at a higher pitch and slower tempo than non-infant-directed songs, but also the singers display a more loving or smiling tone in their voices in the former case (Trehub & Zacharias, 1998). But we know almost nothing about mothers' emotional expressions when singing or playing taped music to their infants. Research has shown that when infants are exposed to music they show, among other behaviours, smiling, vocalising and engagement (Holahan, 1987; Kelley & Sutton, 1987; Papousek & Papousek, 1981; Trehub, 1993). Moreover, Rock et al. (1999) observed that 6-month-old infants' smiling and looking at their singing caregiver are indicative of their engagement in a musical interaction. However, these studies did not provide any quantitative measurement, nor did they look at the role of physical contact or age.

During interactions in which mothers sing to their infants, do infants touch their mothers? How much do they smile? To what extent do infants show active attempts to communicate? What are the features of the infants' emotional state and degree of engagement when their mothers sing to them? Do the infants' communicative-affective behaviours, emotional state and degree of engagement change according to singing context and age? What is the level of the mothers' physical contact, affectionate gestures and smiling when they sing during interactions with their infants? Does the mothers' level of communicative-affective behaviours differ in relation to the infants' age and to the presence or absence of physical contact? These are questions addressed in this section.

Because physical contact is so important in the first few months of life, it is predicted, in relation to the infant's communicative-affective behaviours, that infants will make more physical contact with their mothers at 3-4-months of age than at 7-8 months. I further hypothesise that the infant will smile more often during the touch context at 3-4 months compared to the no-touch context at 3-4 months. However, it is expected that in the touch contexts there will be no difference in amounts of smiling between 3-4 months and 7-8 months of age. In relation to the infant's active attempts to communicate, because after 6 months of age infants start babbling, infants are predicted to produce more active attempts to communicate at 7-8 months compared to 3-4 months. With respect to the infant's emotional states and degree of engagement, the infant is expected to show similar positive emotional states and a high degree of engagement during the touch context at both 7-8months and at 3-

4 months. But, during the no-touch context, I predict that infants will display less positive emotional states and a lower degree of engagement compared to the touch context.

In relation to the mother's communicative-affective behaviours and according to Trainor et al. (1997) findings, it is hypothesised that the mother will smile while singing. Moreover, mothers will show more smiling, affectionate gestures and physical contact with the infant at 3-4-months of age compared to 7-8-months of age. This is because at 3-4 months the interaction is based more on face-to-face interaction and is dyadic, compared to 7-8 months when the interaction includes also objects and becomes triadic. Moreover, because at 3-4-months of age the infant is so sensitive to physical contact I predict that, in the no-touch context, the mother will increase the amount of smiling compared to the touch context. In fact, the mothers might display more smiling in the absence of physical contact in order to reassure their infants.

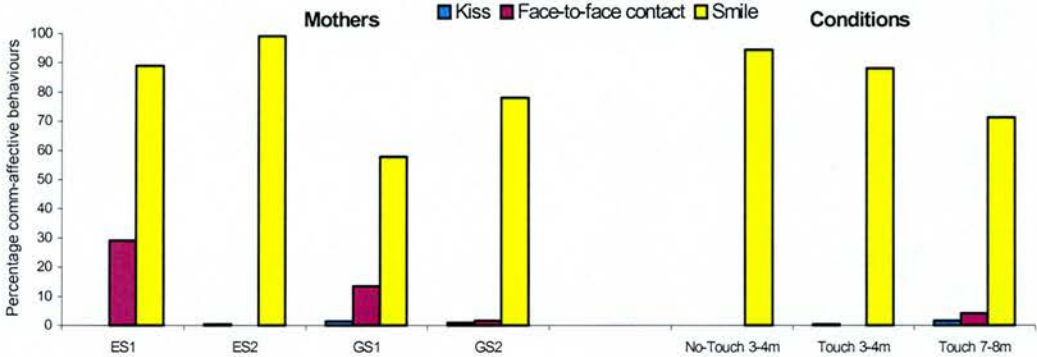
In order to test these hypotheses the infants' and mothers' communicative-affective behaviours are analysed using the dataset presented in Chapter 3, section 3.1.2. The dataset was acquired by asking the mothers to sing songs to their infants in different conditions. When their infants were 3-4 months of age, mothers were asked to sing to their infants in two contexts: no-touch and touch, and to their 7-8 month-old infants in the touch context only. The infant's communicative-affective behaviours include: touching (mothers, self or toy), active attempts to communicate, and smiling. The mother's communicative-affective behaviours include: touching infant, affectionate gestures such as kissing and face-to-face contact, and smiling. The procedures used to measure the partners' communicative-affective behaviours were explained in Chapter 2, section 2.3.1.2. Moreover, the infant's emotional states in terms of: very happy, happy, neutral, unhappy and very unhappy states, as well as their degree of engagement in terms of: high engagement, engagement, little engagement and no engagement were analysed. The procedure to measure the infant's emotional states and degree of engagement was explained in Chapter 2, section 2.3.1.3.

4.2.1 Mothers' and infants' communicative-affective behaviours in interactions with songs

This section examines the mothers' and the infants' communicative-affective behaviours displayed during interactions based on songs. In Figure 4.10, the mothers' kissing, face-to-face contact and smiling behaviours are reported, expressed as a percentage of the total duration of the interaction. The amount of the mother's touching the infant is displayed in

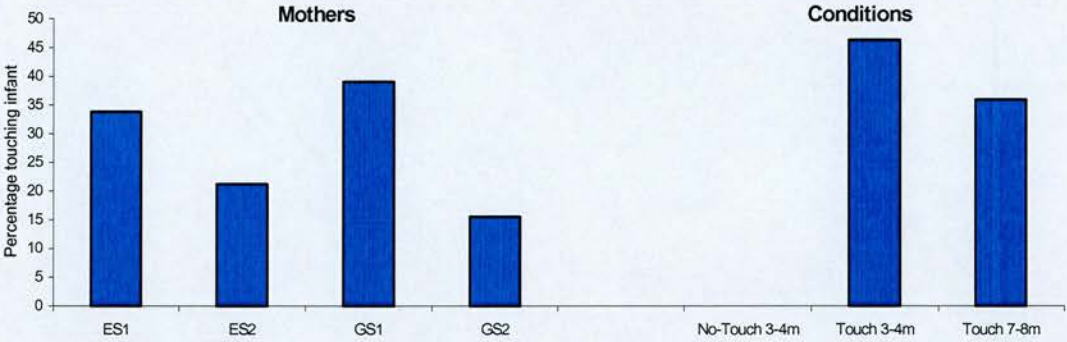
Figure 4.11, expressed as a percentage of the mother’s potential overall amount of touching her infant. The infant’s communicative behaviours are displayed in two different figures. In Figure 4.12 the infant’s smiling and active communicative effort are expressed as a percentage of the total duration of the interaction. In Figure 4.13 the amount of the infant’s touching the mother, self and toy are expressed as a percentage of the infant’s overall amount of touching.

Figure 4.10 Mothers’ kissing, face to face contact and smiling, expressed as a percentage of the total duration of the interaction, as a function of mother, context and age



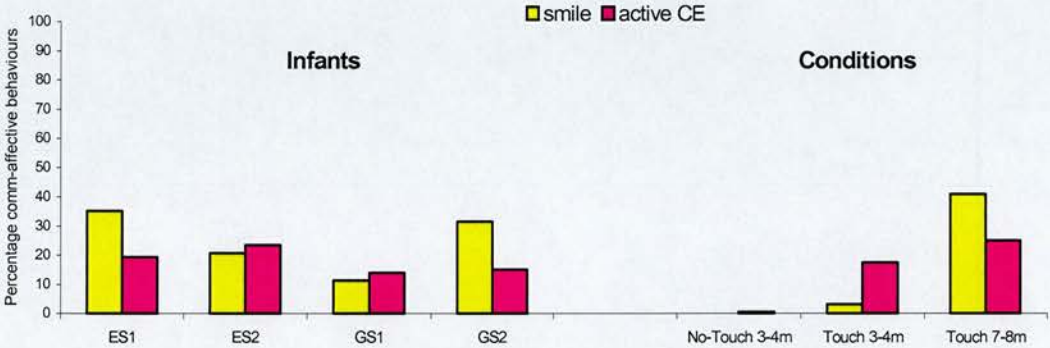
First of all, from Figure 4.10 it emerges that when mothers sing to their infants they smile for long periods. In particular the ES mothers smile somewhat more than the GS mothers. Only the ES1 and GS mothers show some face-to-face contact with their infants. At 3-4 months mothers display a similar percentage of smiling in the no-touch and touch contexts. However, in the touch contexts mothers smile more frequently with 3-4 months olds compared to 7-8 months olds. Overall mothers produce a very small percentage of affectionate gestures, i.e., kissing and face to face contact, which they tend to display in the 7-8 months context.

Figure 4.11 Mothers' touching of their infants, expressed as a percentage of the potential overall amount of touching the infant, as a function of mother, context and age



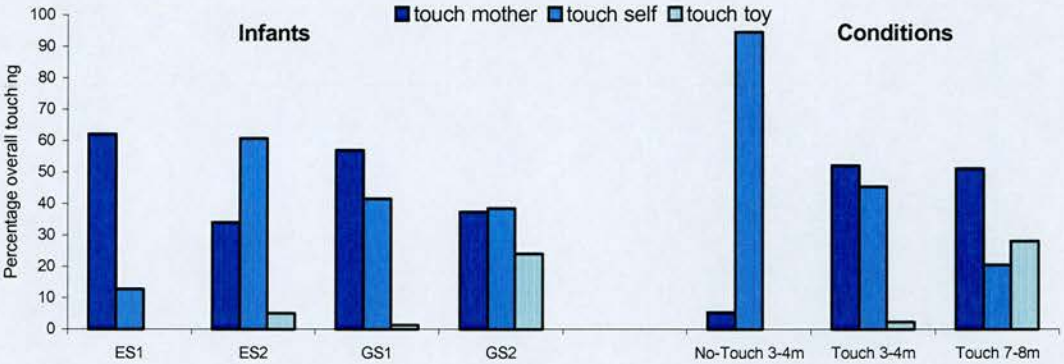
As Figure 4.11 shows, all the mothers make some physical contact with their infants, with the ES1 and GS1 mothers touching their infants slightly more than the other mothers. With respect to context, mothers touch their infants more at 3-4 months than at 7-8 months.

Figure 4.12 Infants' smiling and active communicative effort, expressed as a percentage of the total duration of the interaction, as a function of infant, context and age



All infants show some smiling and active communicative effort, as displayed in Figure 4.12. In particular the ES1 and GS2 infants tend to smile more than the other infants. With respect to context, it is interesting to note that at 3-4 months infants do not smile at all in the no-touch context and only a little in the touch context. By contrast, at 7-8 months they display long periods of smiling. Similarly, when the infants' active communicative effort is considered, they display practically no attempt to communicate in the no-touch context. However, again at 7-8 months infants appear to make more effort to communicate than at 3-4 months.

Figure 4.13 Infants' touching of mother, self and toy, expressed as a percentage of the total duration of touching, as a function of infant, context and age

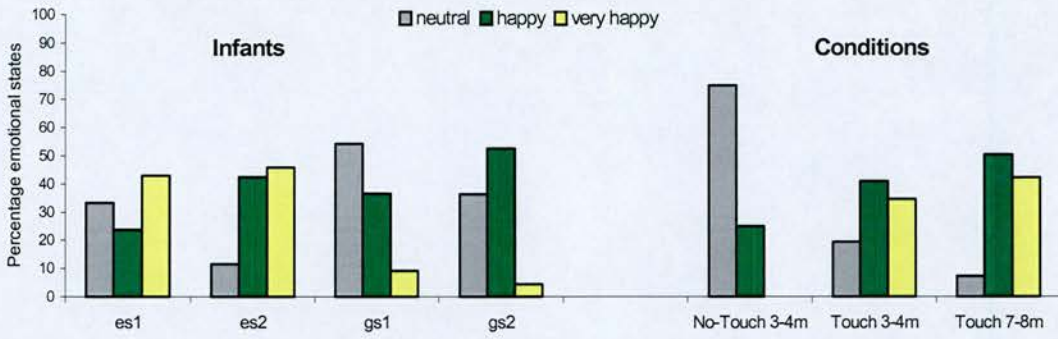


The data displayed in Figure 4.13 suggest that all infants produce some physical contact with their mothers and self, but not all infants touch the toy. Moreover, the ES1 and GS1 infants touch more often the mother than they touch themselves or the toy. By contrast, the ES2 infant displays long self touching compared to touching her mother or the toy. Only the GS2 infant touches similarly the mother and self, with the toy being slightly less often. During the no-touch context infants display more self touching than in the touch context at 3-4 months, and only occasionally do they touch their mothers. With respect to age, infants touch similarly their mothers at both 3-4 months and 7-8 months. However, at 7-8 months infants display less self touching and more toy touching than they do at 3-4 months.

4.2.2 Infants' emotional states and degree of engagement

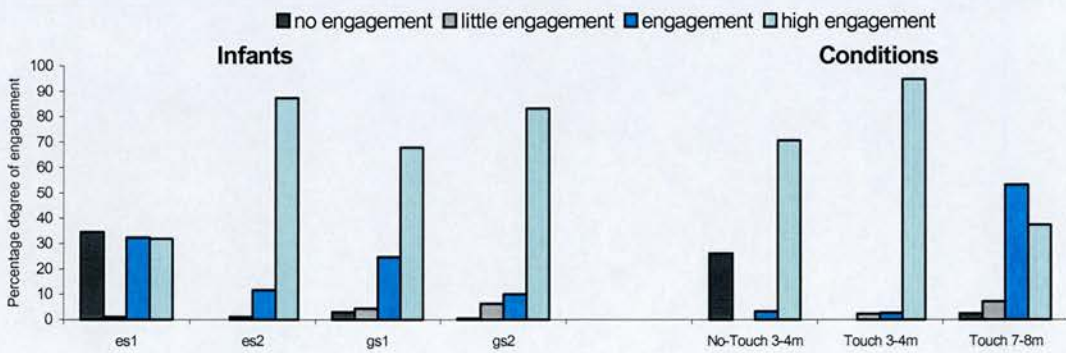
In this section I explore infants' emotional states and degree of engagement which are expressed as a percentage of the overall duration of the interaction. The infants' emotional states include: very unhappy, unhappy, neutral, happy, and very happy. Because infants did not show either very unhappy nor unhappy states, these categories are not shown in Figure 4.14. The infants' degree of engagement includes: no engagement, little engagement, engagement and high engagement, as shown in Figure 4.15. In both figures the infant's states are expressed as a percentage of the total duration of the interaction.

Figure 4.14 Infants' emotional states expressed as a percentage of the total duration of the interaction, as a function of infant, context and age



First, it is interesting to observe that the infants are either in a neutral or positive state during interactions in which their mothers sing songs, since there are no occurrences of unhappy states. The ES infants display longer positive states compared to the GS infants, with the GS1 infant showing the longest neutral state. During the no-touch context at 3-4 months, infants spend more time in a neutral state and less time in happy states than they do in the touch context at the same age. However, at 3-4 months infants spend less time in happy and very happy states than they do at 7-8 months.

Figure 4.15 Infants' degree of engagement expressed as a percentage of the total duration of the interaction, as a function of infant, context and age



As Figure 4.15 shows, aside from the ES1 infant, the other infants display high engagement more than any other level of engagement. With respect to context, in the no-touch context at 3-4 months infants display long periods of no engagement compared to the touch context. On the other hand, during the touch context at 3-4 months infants show high engagement which lasts almost throughout the entire interaction. At 7-8 months infants are less often highly engaged but are more frequently engaged compared to the 3-4 months.

4.2.3 Discussion and conclusions regarding infants' and mothers' communicative-affective behaviours

As predicted, mothers smile a great deal when singing to their infant. This is consistent with Trainor et al.'s (1997) findings that raters suggested that mothers sounded as if they were smiling while singing. These authors found that smiling changes the quality of the voice of the mothers, focusing the energy in the lower frequencies typical of infant-directed but not of infant-absent singing. According to Scherer (1986), pleasant emotions cause the expansion of the faucal and the pharynx muscles, giving the acoustic characteristic of a wide voice. As predicted, during the no-touch context mothers smile longer compared to the touch context. In fact, in the absence of physical contact mothers smile almost all the time, perhaps trying to convey positive emotions and to reassure their infants. Also mothers were predicted to display more smiling, kissing and face-to-face contact in the touch context at 3-4 months compared to 7-8 months. Although mothers tended to smile longer at their 3-4 month-old infants than at 7-8 month-olds, they were observed to display more affectionate gestures to the older infants. Therefore it seems that at 7-8 months mothers have other means for communicating pleasant emotions to their infants. It could be that in the early months mothers and infants relate mostly through face-to-face interaction, with the mothers therefore producing long periods of smiling in order to communicate positive emotions. But when the infants are older and the interaction is more triadic, mothers express their positive emotions through other means, e.g., kissing and face-to-face contact. Analysis of the mothers' physical contact with their infants reveals that at 3-4 months mothers touch their infants more than at 7-8 months; this is in line with my prediction. In fact, at 3-4 months physical contact is a major channel of communication between partners, and both mother and infant seek proximity and contact. Therefore, while singing to their infants, not only mothers try to attract their infants' attention, regulate their states, and convey their cultural and personal background (see Chapter 3, section 3.1.2), they also attempt to communicate emotions. Through smiling and making physical contact with their infants while singing to them, mothers may communicate to their infants positive states of reassurance, love and care. Thus, music may serve as a powerful medium for conveying feelings and emotions in the first months of the infant's life.

Analysis of the infant's communicative-affective behaviours showed that, contrary to my expectation, infants display similar percentage of touching their mothers at 3-4 months as well as at 7-8 months. Thus it seems that in interaction with songs infants search for physical contact with their mothers and this does not change with age. As predicted infants smile for

longer periods during the touch context at 3-4 months compared to the no-touch one. In fact, infants do not show any smiling at all in the absence of physical contact, suggesting that they may feel distressed. Although it was expected that infants would display similar amounts of smiling at both ages in the touch contexts, I found that at 7-8 months they smile more than at 3-4 months. It could be that at around 3-4 months songs serve more a function of communication whereas when infants are older songs become part of their social play. When the infant's active communicative effort is considered I found, as predicted, that at 7-8 months infants show a higher degree of active communicative efforts than they do at 3-4 months. This is consistent with the fact that after 6 months of age infants increase their vocalisations and at around 7-8 months they produce babbling sounds which are often regarded as prerequisites of later vocal communication (Fogel, 1997).

In line with my prediction, during the no-touch context infants predominantly display little happy state and very long neutral emotional states compared to the touch context at 3-4 months. Moreover, as hypothesised, infants show no simple levels of engagement during the no-touch context; rather they long high engagement levels. Therefore it seems that in the absence of physical contact infants are slightly disoriented in terms of their emotional states and degree of engagement. With respect to age, it was predicted that infants would show a similar percentage of positive emotional states and high degree of engagement at both 3-4 months and 7-8 months. However, contrary to my expectation, at 7-8 months infants are more often happy and very happy than at 3-4 months. It could be that when they are older, infants' songs becomes a way for the partners to have fun together. On the other hand, in contrast with my expectation, at 3-4 months infants display high engagement for almost the entire duration of the songs, whereas when older, although still engaged, their high engagement decreases. Thus, when the infant is older music can be part of social play between partners, although the infant seems to have lost some of the interest that he showed earlier. The reason could be that music brings mother and infant closer which is important in the early months of the infant's life, but that as he grows older he becomes more interested in external events. Thus music can no longer serve its dyadic function of 'framing' the partners of the interaction because, as the infant gets older, his attention turns to the world outside the immediacy of the dyad. Therefore, although some previous authors simply noted that infants display engagement, smiling and enjoyment, these findings show that infants change these as a function of context and age.

In sum, with respect to the infant's communicative-affective behaviours, it was predicted that infants would show more physical contact with their mothers at 7-8 months than at 3-4 months. Contrary to my expectation, infants display a similar amount of touching mothers at both ages. Moreover, it was predicted that infants would smile longer in the touch context compared to the no-touch one. In line with my prediction, in the no-touch context infants do not smile whereas in the touch context they display some smiling. Although it was expected that there would be no difference in the amount of smiling in relation to age, infants smile longer when older. With respect to the infant's active communicative effort (CE), infants were expected to produce more active CE at 7-8 months than at 3-4 months. Indeed, when older infants show an increase of active CE, thus confirming my prediction. Regarding the infant's emotional states and degree of engagement, infants were expected to display less positive emotional state and degree of engagement in the no-touch context compared to the touch one. In fact, infants show frequent neutral states and no engagement in the no-touch compared to the touch context. Finally, infants were expected to show similar amounts of positive emotional states and high degree of engagement at both 7-8 months and 3-4 months. However, my findings contradict this prediction. In fact, although 7-8 month olds display longer positive emotional states they reduce their degree of high engagement compared to 3-4 months.

With respect to the mothers' communicative behaviours, they were expected to smile while singing to their infants, and in fact they do so. In particular, it was hypothesised that mothers would smile longer in the no-touch context compared to the touch one. Indeed, they smile almost all the time in absence of physical contact. Mothers were also expected to display a higher level of smiling, touching infant, kissing and face-to-face contact at 3-4 months than at 7-8 months. This prediction was partially confirmed in that the mothers show longer smiling and physical contact with their infants at 3-4 months. However, mothers increase kissing and face-to-face contact with their infants at 7-8 months compared to 3-4 months.

4.3 How do mother and infant relate to the phrasing structure of the song?

As discussed in Chapter 3, one of the particularities of music resides in its hierarchical structure which I predicted the mother would stress when singing songs to her infant. An interesting aspect of this hierarchy is phrasing structure. According to Trainor and colleagues (1997), when singing the mother marks the boundary of the phrase, lengthening the duration

of the last beat. Moreover, it is known that 4½- and 6-month-old infants are sensitive to the lengthening between phrases but not within phrases (Krumhansl & Jusczyk, 1990). Although these studies recognise separately the mother's emphasis of these boundaries and the sensitivity of the infant to them, they failed to explore the effect of this structure on interaction. Thus, a number of questions remain unanswered and merit further investigation: How do mother and infant relate to the phrases of the song? In particular, is the mother/infant likely to produce a burst of activity in one phrase and much less activity in another, or do they show an even distribution of behaviours across phrases? If the mother/infant shows a different level of activity in different phrases of the songs, is this related to physical contact? Does the age of the infant count? Is the level of activity in the phrases of the songs related to the musical tempo of the songs?

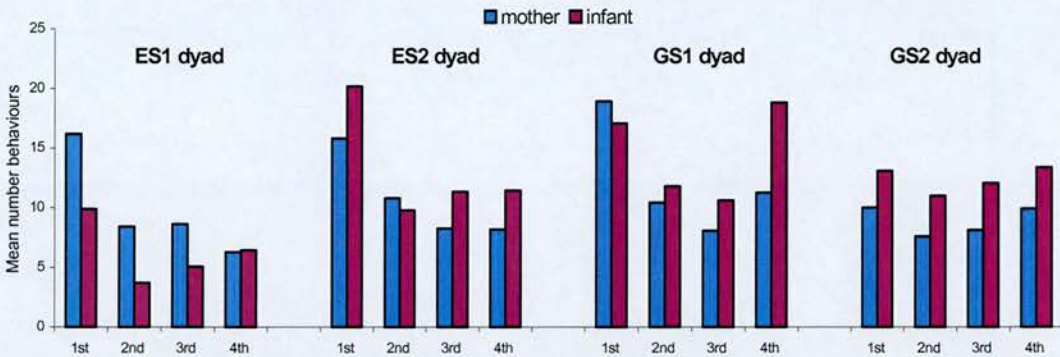
If the partners are sensitive to the temporal structure of the song, they are expected to vary their level of activity across the phrases of the song. Moreover, the variation of level of activity is predicted to be more marked when the infant has reached 7-8-months of age compared to 3-4-months. This is because at 7-8 months they are more used to interactions animated by songs, and they are more familiar with the temporal organisation and phrasing structure of such songs. Consequently their participation in the phrases of the song should be less even. On the other hand, variation in the level of activity of the partners in the phrases of the song is not expected in relation to physical contact when the infant is 3-4-months of age. In fact, the infant's participation in the phrases of the songs should be related to the temporal structure of the song independently of physical contact with the mother. No specific prediction is made in relation to the musical tempo of the song nor to either the mothers' or the infants' level of activity. Moreover, if the partners vary their level of activity in the phrases of the songs, there is no specific expectation regarding the phrase in which they will produce the majority of their behaviours. In order to evaluate these hypotheses mothers' and infants' level of activity in the phrases of the song is analysed, using the dataset presented in Chapter 3, section 3.1.2. Mothers were asked to sing songs to their infants at 3-4-months in two different contexts: no-touch and touch, and to their 7-8 month-olds during the touch context only. The partners' physical and communicative-affective behaviours were measured in each phrase of the song across different contexts and ages.

4.3.1 Mothers' and infants' level of activity in the phrases of the song

In this section the level of activity performed by each partner in the phrases of the song is examined. In particular, Figures 4.16 to 4.17 show how each partner of the dyad participates

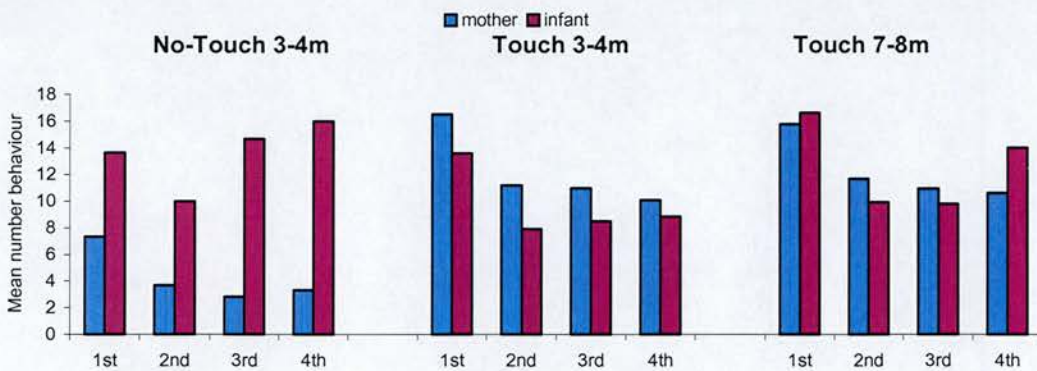
in the phrases of the song, on the basis of the mean number of physical and communicative-affective behaviours each partner produces in each phrase of the songs as a function of dyad and condition. Therefore while in sections 4.1 and 4.2 data were based on durations, in this section data express the frequency of behaviours each partner performs in each phrase of the song averaged across song performances.

Figure 4.16 Mothers' and infants' mean number of behaviours for each phrase as a function of dyad



As Figure 4.16 shows, overall both partners of the dyad seem to produce more behaviours in the 1st phrases of the song compared to the others. Moreover, the GS dyads tend to perform numerous behaviours in the 4th phrase of the song also. Apart from the ES1 infant, the infants of the other dyads appear to produce more behaviours than their mothers in some phrases of the song.

Figure 4.17 Mothers' and infants' mean number of behaviours for each phrase, as a function of context and age



At both ages mothers and infants appear to produce their highest level of activity in the 1st phrase of the song. In the no-touch context, although mothers still show a similar pattern to the touch context, infants distribute their behaviours differently. Two two-way mixed

ANOVAs were carried out to statistically test these qualitative impressions about the effect of phrase on the number of the partner's behaviours. One within factor, i.e., phrase (x4 levels, i.e., the number of phrases in the song) and one between factor, i.e., condition (x3 levels, i.e., no-touch 3-4 month, touch 3-4 months, and touch 7-8 months) were considered. The analysis of variance was applied to the level of activity produced in all song performances for each condition.

Both partners display a significant main effect of phrase on their level of participation (mothers, $F(3, 129) = 13.08, p = .00001$; infants, $F(3, 129) = 4.48, p = .005$) and only the mothers show a significant main effect of condition ($F(2, 43) = 4.61, p = .015$). I explored these effects comparing mothers' and infants' levels of activity across phrases. Bonferroni correction for multiple comparisons was employed, yielding a new level of threshold for significance of $p = .008$. Mothers produce significantly more behaviours in the 1st phrase of the song compared to the other phrases (t-tests 2-tailed (paired) 1st phrase vs 2nd phrase $t = 6.57, df = 45, p = .00001$, 1st phrase vs 3rd phrase $t = 6.28, df = 45, p = .00001$; 1st phrase vs 4th phrase $t = 6.09, df = 45, p = .00001$). Also the infants display to produce significantly more behaviours in the 1st phrase of the song compared to the 2nd and the 3rd but not the 4th phrase (t-tests 2-tailed (paired) 1st phrase vs 2nd phrase $t = 8.96, df = 45, p = .0001$, 1st phrase vs 3rd phrase $t = 7.94, df = 45, p = .00001$; 1st phrase vs 4th phrase $t = 5.52, df = 45, p = ns$).

Figure 4.18 Mothers' and infants' mean number of behaviours for each phrase, as a function of the musical tempo

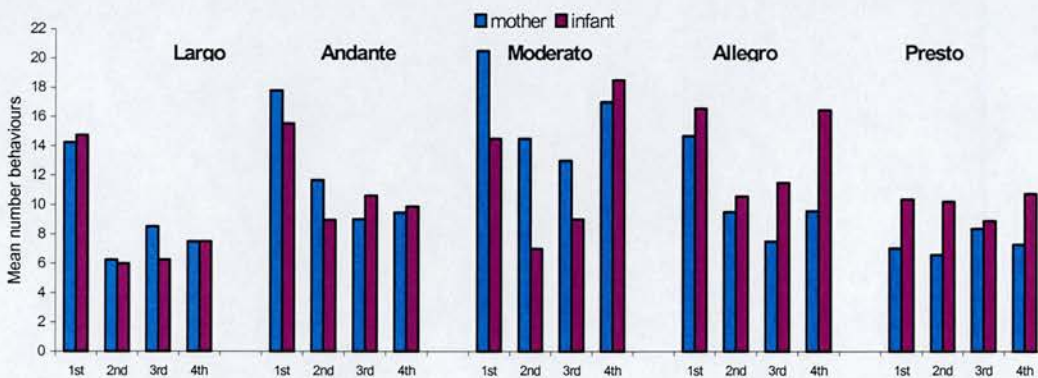


Figure 4.18 shows that also when the musical tempos of the song are considered, both partners of the dyad display different levels of activity in the phrases of the songs. Two two-way mixed ANOVAs (one for the mothers and another for the infants) examined the effect of phrase on the number of the partners' behaviours in relation to the musical tempo of the song. Two factors were considered: a within factor, phrase (x4 levels, i.e., number of phrases

of the song) and a between factor, musical tempo (x5 levels, i.e., *largo*, *andante*, *moderato*, *allegro*, and *presto*). The analysis of variance was carried out on the level of activity performed by the partners in all performances for each musical tempo.

Both partners show a significant effect of phrase on the level of activity in the phrases of the song across the musical tempos (mothers, $F(3, 117) = 13.49, p = .0001$; infants, $F(3, 102) = 3.83, p = .012$), but they do not show a significant main effect of musical tempo. Moreover, mothers display a significant interaction between musical tempo and phrase of the song ($F(12, 117) = 2.26, p = .013$). Post-hoc comparisons employed the Bonferroni correction for multiple comparisons, yielding a new threshold for significance of $p = .008$. Pairwise comparisons show that mothers display a significant effect of phrase on behaviours in the 1st phrase of the song during *largo*, *andante* and *allegro* tempos (t-tests 2-tailed (paired), 1st phrase vs 2nd phrase $t = 7.51, df = 34, p = .00001$; 1st phrase vs 3rd phrase, $t = 8.95, df = 34, p = .00001$; 1st phrase vs 4th phrase $t = 6.43, df = 34, p = .00001$). On the other hand, infants do not show a significant interaction between musical tempo and phrases of the song on the amount of behaviours. Pairwise comparison show that the significant main effect of phrase on amount of the infants' behaviours depends on higher activity in the 1st phrase of the song compared to the 2nd and 3rd phrases but not the 4th phrase (t-tests 2-tailed (paired) 1st phrase vs 2nd phrase $t = 4.12, df = 38, p = .00001$; 1st ph vs 3rd ph, $t = 3.94, df = 38, p = .0001$; 1st phrase vs 4th phrase $t = 2, df = 38, p = ns$).

4.3.2 Discussion and conclusions regarding relationships between phrasing structure and level of activity

Overall mothers and infants appear to distribute their behaviours in similar patterns across the phrases of the song. In fact, both partners tend to produce a higher number of behaviours in the 1st phrase compared to the others. Analysis of variance of the mothers' and infants' behaviours in the phrases of the song in relation to conditions showed that both partners of the dyad show a significant effect on the organisation of their behaviours in the phrases of the song independently of context or age. Moreover, pairwise comparison showed that mothers produce significantly more behaviours in the 1st phrase of the song compared to the other phrases. Also, infants display a significantly higher amount of behaviours in the 1st phrase of the song compared to the 2nd and 3rd but not the 4th phrase of the song. With respect to the musical tempo of the songs, analysis of variance showed a significant effect of phrase on the level of activity that both partners produce in the phrases of the song across musical tempos. Mothers also display a significant interaction between musical tempo and

number of behaviours in the different phrases of the songs. This suggests that mothers vary their level of activity in the phrases of the songs according to the musical tempo, thus making their singing predictable. In particular, with *largo*, *andante* and *allegro* tempos mothers display a significantly higher level of activity in the 1st phrase of the song. Thus mothers may sing more often songs at the *andante* and *allegro* tempos (see Chapter 3, Figure 3.1) because they allow a temporal change in the interaction, while at the same time leaving open the possibility for them to organise their behaviours in relation to the phrasing structure of the song so as to be predictable. In this way the flow of the musical interaction is ensured and the temporal structure represents the common reference for each partner. On the other hand, there is no significant interaction between the musical tempo of the songs and phrases in the song on the amount of the infants' behaviours. Infants produce significantly more behaviours in the 1st phrase of the song compared to the 2nd and 3rd ones but not the 4th phrase, across tempos. This suggests that across the musical tempos infants also tend to participate mostly at the beginning of the song and to some extent also at the end of the song.

In sum, it was predicted that if mothers and infants were sensitive to the phrasing structure of the song, they would vary their number of behaviours with respect to the phrases of the songs. In fact, both partners display significant differences in amounts of behaviours in the phrases of the song in relation to conditions and musical tempos. In particular, it was hypothesised that infants would be able to display a more marked variation in the phrases of the song at 7-8 months compared to 3-4 months. Moreover, it was predicted that physical contact would not affect infants' participation in the phrases of the song. Data showed that infants' amount of behaviours in the phrases of the song are not related to either context or age, thus contradicting my hypothesis that infants would show a stronger effect at 7-8 months, but confirming my expectation that physical contact would not affect the partners' level of activity across the phrases of the song. Although no prediction was made regarding the phrase of the song in which the partners would participate the most, both partners showed a significantly higher level of activity during the 1st phrase of the song. However, the infants display no significant difference between the 1st phrase and the 4th one, suggesting that they produce a high number of behaviours in the 4th phrase also. No specific prediction was made in relation to the musical tempo of the songs or the effect of phrase on the partners' activity in the phrases of the song. However, it turned out that both partners displayed a significant effect of number of behaviours across the different phrases in relation to the musical tempo of the songs. Mothers showed different levels of activity across different phrases and musical tempos. They displayed higher levels of activity in the 1st

phrase during the *largo andante* and *allegro* tempos only, whereas infants did so across all tempos.

4.4 Summary of the chapter

This chapter considered the physical and communicative-affective behaviours of both partners during interactions based around songs, and also examined how partners distribute their behaviours across the different phrases of the songs.

Section 4.1 investigated how the level of activity of both partners is affected by physical contact. In particular, infants' cyclical activity turned out to be more affected by context than age. On the other hand, mothers' cyclical behaviours, which represent a large portion of their behaviours, appear to be more affected by the infants' age. In fact, at 7-8 months mothers decrease their cyclical activity, suggesting that rhythmical behaviours might play an important role in the first months of life for communicating with their infants. Moreover, rhythmical behaviours might serve to attract and maintain infants' attention, and also to interlock the partners' activity in a smooth interaction. This might be facilitated by the fact that mothers' cyclical behaviours involve different modalities, i.e., visual, kinaesthetic, and tactile, which change and adjust in relation to the infant's development and the terms of interaction. On the other hand, infants' cyclical activity represents only 25% of their overall activity and does not increase markedly between the ages of 3-4 and 7-8 months. However, a closer look at the infants' cycles reveals that context and age affect the kind of cycles they produce. Given the importance of cyclical behaviours in infancy, musical interaction might facilitate the infant's motor development. In interactions based around songs, the musical tempo of the song seems to play an important role. In particular, both partners display different levels of activity, as well as different amounts and types of cyclical behaviours depending on the musical tempo of the songs.

Section 4.2 explored the mothers' and infants' communicative-affective behaviours in interactions based around songs. It was argued that through songs mothers convey love and care, and hence that music is a powerful medium for communicating feelings and emotions. Infants' communicative-affective behaviours are affected by context, i.e., distress in the no-touch context, but also by age, i.e., more smiling, less self-touching and more vocalisation at 7-8 months. Overall the infants' emotional states were affected by context, i.e., in the no-touch context infants spend more time in neutral states than they do in the touch context, and by age also, i.e., happy and very happy states are more prevalent at 7-8 months than at 3-4

months. On the other hand, infants' degree of engagement is mainly related to age. In fact, at 3-4 months in general, and in the touch context in particular, infants display the greatest amount of high engagement. Therefore, musical interaction seems to change function in relation to the infant's age. Perhaps, at 3-4 months songs play a central role in the interaction, giving the partners a common temporal reference onto which to interlock and communicate with one another. At 7-8 months, by contrast, interaction with song plays a less crucial role in the interaction and becomes one of sharing and having a good time together

Finally, section 4.3 analysed the partners' distribution of behaviours across the different phrases of the song. Both partners of the dyad participated significantly in the phrases of the song independently of context and age. Although mothers display a significant amount of behaviours in the 1st phrase of the song across contexts and age, infants show a different pattern. In fact, infants show a significantly higher activity in the 1st phrase of the song compared to the 2nd and 3rd phrases but not in the 4th one. This suggests that in the 4th phrase infants produce a high number of behaviours similarly to the 1st phrase. With respect to the musical tempos of the songs, mothers and infants display a significant effect of level of activity in the phrases of the songs. Moreover, mothers show a significant interaction between phrases and musical tempo suggesting that according to the musical tempo they vary their number behaviours in the phrases of the song. Further analyses showed that mothers participate significantly in the 1st phrase of the song during *largo*, *andante* and *allegro* tempos. By contrast, infants show a significant effect of the 1st phrase of the song across all tempos and compared to the 2nd and 3rd phrases but not the 4th one. Therefore, a possible reason for mothers frequently singing certain tempos more than others (see section 3.1.4) may be that it is at some tempos that both partners find it easier to understand the temporal structure of the musical event and to organise their behaviours accordingly.

Musical interaction involving songs thus appears to be a special context in which partners can organise and regulate their participation thanks to the temporal structure provided by the musical event. Therefore, music may not only serve to communicate emotions and as a means of sharing a pleasant time together but, through its underlying structure, music may also highlight the basic structure of interaction and ultimately of communication. In this way, infants can be introduced to the pragmatics of communication through songs.

The next chapter will examine in more detail how both partners relate to the temporal structure of the song, by looking at the extent to which they synchronise different aspects of their own behaviour with self, with the musical beat, and with their partner's behaviours.

CHAPTER FIVE

Synchronisation in musical interaction

According to Fraisse (1982), synchronisation occurs when response and stimulus are produced simultaneously. The matching of response and stimulus can happen only when there is anticipation, e.g., the sequence of events is periodic. Although anticipation is easier when there is an isochronous rhythm, i.e., a sequence of stimuli at identical distances, it is also possible with complex rhythms.

In this chapter mothers' and infants' synchronisation in interaction with songs is examined with respect to the following:

- 1) self-synchrony, i.e., internal motor co-ordination (section 5.1)
- 2) synchrony with the musical beat (section 5.2)
- 3) synchrony between the mother's and infant's activity (section 5.3)

5.1 Do mother and infant organise their behaviours in self synchrony?

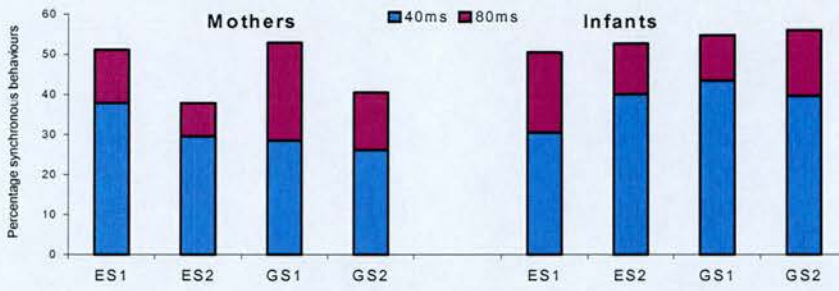
In order to synchronise with an external stimulus, both mother and infant must be able to co-ordinate their activity internally. Hence, each partner of the dyad has to organise and co-ordinate several parts of the body, and perhaps the voice at the same time (Condon, 1979). Gratier and Devouche (2000) explain the partner's self synchrony as the channelling through voice, gestures or gaze of the same expression. When in normal interaction with their infants, mothers organise their behaviours in self-synchrony. In fact, research by Sullivan and Horowitz (1983) found that when in interaction with their infants mothers tightly co-ordinate their vocal, tactile, visual or kinaesthetic stimuli. However, the ability to co-ordinate behaviours internally is not peculiar to adults only. Infants also have been noted to do so. For example, Condon (1979) observed that even 1- to 4-day-old newborns are well co-ordinated and self-synchronous. Even foetuses have been found to organise their behaviours when in their mother's womb (Hepper et al., 1993). Thus, these studies stress the importance of the partners' internal co-ordination during normal mother-infant interactions. What happens when songs are included in the interaction? Do mother and infant show internal synchrony during interactions with songs? If so, how accurate are these synchronisations? Does physical contact or the lack thereof affect the infant's self-synchrony? Does the infant's age play a role in the quality and quantity of internal co-ordination?

Both mother and infant are predicted to present internal organisation during interactions based around songs. Further, physical contact is hypothesised to have an effect on the infant's internal co-ordination and accuracy. In the touch context, the infant will, I hypothesise, find it more difficult to match accurately his own behaviours compared to the no-touch context, because physical contact with the mother might render his behaviours less smooth. It is further predicted that at 7-8 months of age, the infant will be more co-ordinated and precise than at 3-4-months. In order to evaluate these hypotheses the dataset of interactions was analysed, based on the songs presented in Chapter 3, section 3.1.2. This was obtained by asking mothers to sing songs to their 3-4-months old in two contexts: no-touch and touch, and to their 7-8-months old infants only in the touch context. As explained in Chapter 2, section 2.3.2, synchronisation was deemed to occur when onset behaviours occur within 40ms (strict criterion) and 80ms (lenient criterion) latencies. Then the amount of self synchronous behaviours in relation to the overall amount of behaviours performed by each partner was measured. Finally, the mean distance between the onset behaviours that were in self-synchrony was measured to evaluate the accuracy of the partner's internal co-ordination.

5.1.1 Analysis of mothers' and infants' self synchrony

This section examines the mothers' and infants' internal synchronisation. All the partners' onset behaviours are compared, i.e., communicative-affective and physical behaviours, between each other, self-synchrony occurring within a temporal window of 40ms (from 0ms to 40ms), and 80ms (from 0ms to 80ms). The procedure to assess the mother's and the infant's self synchronisation is explained in Chapter 2, section 2.3.2.1. The focus of this section is on: a) the overall amount of internally co-ordinated movements performed by the partner, expressed as a percentage of the overall amount of behaviours produced in the interaction; b) the mean distance between the onset of the partner's behaviours in synchrony, i.e., within 40/80ms interval, expressed in milliseconds (in this case the smaller the bar, i.e., closer to '0', the more accurate is the mean distance between onsets time).

Figure 5.1 Percentage of mothers' and infants' behaviours that are self-synchronous, as a function of dyad, collapsed across conditions



First of all it is interesting to observe from Figure 5.1 that infants tend to display an overall higher percentage of self-synchronous behaviours compared to their mothers, especially at 40ms latency. Furthermore infants produce a similar percentage of self-synchronous behaviours during interaction with songs. At 40ms latency, only the ES1 infant seems to move somewhat less often in self-synchrony. Across mothers, it is the ES1 mother who produces a higher percentage of self-synchronous behaviours at 40ms latency, compared to the others.

Figure 5.2 Percentage of mothers' and infants' behaviours that are self-synchronous, as a function of context and age

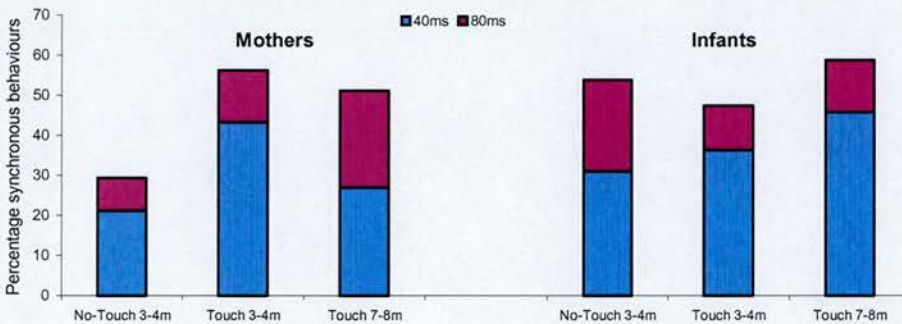
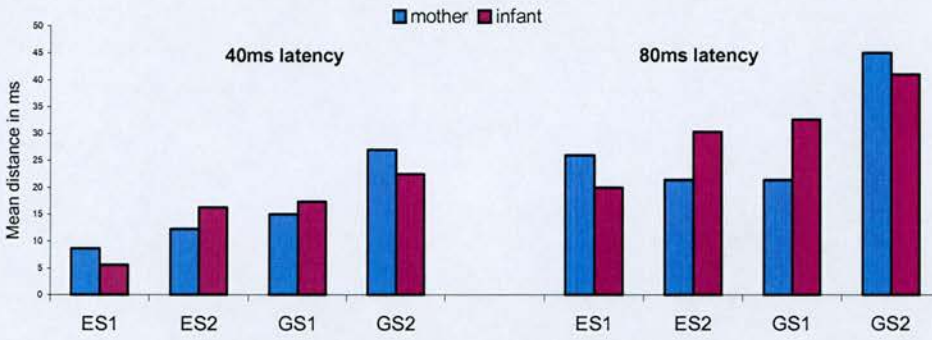


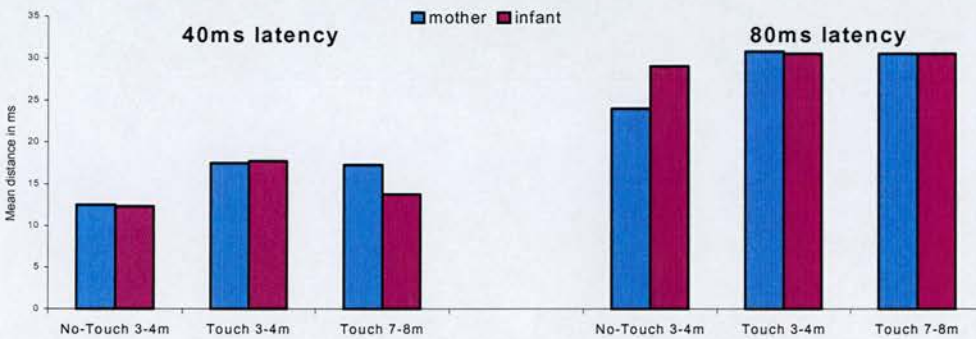
Figure 5.2 shows that, when interacting with their 3-4 month old infants, mothers co-ordinate a higher percentage of their behaviours during the touch context than during the no-touch context. Mothers decrease the amount of self-synchronous behaviours at 7-8 months compared to 3-4 months. Also infants appear to produce slightly more self-synchronous behaviours during the touch context at 40ms latency compared to the no-touch context. By contrast, at 80ms latency infants display the opposite pattern, producing more self-synchronous behaviours in the no-touch context. With respect to age, infants appear to be more self-synchronous at 7-8 months than at 3-4 months, at both latencies.

Figure 5.3 Accuracy of mothers' and infants' self-synchronous behaviours (mean distances between synchronous behaviours), as a function of dyad



First of all it is interesting to observe from Figure 5.3 that at 40ms temporal window the ES1 dyad is more synchronised in their actions compared to the others. At 80ms latency it is again the ES1 infant who is more precise in comparison to the other infants. The ES2 and GS1 mothers are more accurate in their self-synchronous behaviours than their infants, particularly at 80ms latency. On the other hand, both partners of the GS2 dyad seem to be the least accurate when moving in self-synchrony compared to the other dyads.

Figure 5.4 Accuracy of mothers' and infants' self-synchronous behaviours (mean distances between synchronous behaviours), as a function of context and age



As Figure 5.4 shows, during the no-touch context at 3-4 months both mothers and infants coordinate their actions more precisely, compared to the touch context. This tendency holds at both latencies. However, at 7-8 months infants appear more accurate than at 3-4 months but only at 40ms latency. By contrast, mothers show similar accuracy in self-synchrony at both their infants' ages.

5.1.2 Discussion and conclusions regarding self-synchrony

Self-synchrony implies the ability of the partner to co-ordinate his internally activity. Both partners of the dyad were predicted to be able to organise internally their behaviours in

interactions based around songs. In fact, our analyses show that mothers and infants do move in self-synchrony, organising their activity internally during interaction with songs, thereby confirming our hypothesis. With respect to infants, physical contact was predicted to have an effect on the amount and accuracy of self-synchronous behaviours. In particular infants were expected to be less accurate in the touch context at 3-4 months than in no-touch context. With regard to accuracy, this prediction was supported by the fact that in the no-touch context at 3-4 months infants show more precise self-synchrony compared to the touch context, especially at 40ms latency. Thus, as predicted, physical contact plays a role in the internal organisation of the infants' behaviours, in the sense that in the absence of physical contact they are more accurate compared to when there is physical contact. However, in relation to the amount of self-synchronous behaviours it emerges that infants organise internally a higher amount of behaviours in the no-touch context but only at 80ms latency. Also at 7-8 months infants were expected to produce a higher amount of more precise self-synchronous behaviours than at 3-4 months. In fact, at 7-8 months infants were found to be more accurate in their internal co-ordination compared to 3-4 months, but only at 40ms temporal window. Moreover, when older, infants produce a higher amount of internally organised behaviours at both latencies compared to 3-4 months. Thus, as predicted, age has an effect on the internal co-ordination of the infant in interaction with songs. Interestingly both effects, i.e., physical contact and age, are clearer during 40ms latency than 80ms latency. Moreover, the ES1 infant performs fewer self-synchronous behaviours compared to the GS2 infant although he was more accurate. Thus it appears that for the infants accuracy of co-ordination is not necessarily related to the amount of behaviours in self-synchrony. Overall infants seem to be more precise and produce more self-synchronous behaviours either in the absence of contact or with increasing age.

Apart from the fact that mothers were expected to perform self-synchronous behaviours in interaction with songs, no other prediction was made. In fact, mothers were found to co-ordinate their behaviours internally while singing to their infants. They appeared to produce the majority of self-synchronous behaviours in the touch context at 3-4 months compared to the no-touch context, and this held at both the 40ms and 80ms latencies. Also, when age is taken into consideration, mothers still produced more self-synchronous behaviours at 3-4 months than at 7-8 months. Similarly to their infants, they appeared to be more accurate during the no-touch context compared to the touch one, at both latencies. They did not show differences in accuracy in relation to age. In general, then, mothers and infants appear to be able to internally organise their behaviours during interactions based around songs.

Interestingly, both partners seem to be affected to some extent by context and age in relation to the amount of behaviours produced. Self-synchrony is important for infants because it tells us about their ability to co-ordinate and organise their behaviours during musical interaction. On the other hand, the co-ordination of the mothers' visual, kinaesthetic and tactile patterns is crucial for conveying integrated, multimodal sensory information to their infants even in interactions based around songs.

5.2 Do mother and infant synchronise with the musical beat of songs?

When listening to music, people often accompany the regular sequence of sounds with motor acts. According to Pouthas (1996), adults are able to synchronise their tapping with an auditory stimulus. They are especially accurate when the interval between stimuli occurs between 500 and 750ms, i.e., closer to the spontaneous or preferred tempo. Moreover, adults show a tendency to anticipate the beat by 20 to 50ms (Pouthas, 1996). Several researchers (e.g., Jones & Boltz, 1989; Jones et al., 1993; Klapp et al., 1985) have demonstrated that the timing of adults' motor responses to rhythmic stimuli is influenced by the way in which they attend to those stimuli. Therefore, Drake et al. (2000) suggest that synchronisation with rhythmic stimuli can be assessed through the measurement of motor activity at the onset of sound sequences.

Although synchronisation is cognitively relevant and parents notice their infants rocking to the rhythm of music (Fraisse, 1982), little attention has been paid to whether young infants are able to synchronise with the musical beat. Williams et al. (1933) found that 3-4 year old children are capable of synchronising in time with 500ms interval of the metronome. More recently, Drake et al. (2000) mention that 1-year-old infants perform rhythmic behaviours which are roughly synchronised with music, but no detailed evidence is offered in support of this claim. Is this really possible in early infancy? Moog (1976) hints that 4-6 month-old infants relate their rhythmic behaviours to music, but he provides no clear evidence. Sloboda (1985) criticised sharply Moog's hypothesis arguing that during their first year of life infants show no rhythmic behaviours. In fact, according to Sloboda, in order to be rhythmic, a behaviour has to present one or more of the following features: a) subdivide a beat, b) omit a beat and then re-establish it at the correct time after a pause, c) imitate a rhythmic pattern, and d) move or beat in time to the music. Although the infant's synchronisation with the musical beat has attracted the attention of several researchers, none has effectively tested empirically whether the infant is capable of such synchronisation during musical interaction with the mother.

A number of questions will be addressed in this section about mothers' and infants' synchronisation with the musical beat. Do mothers/infants synchronise with the beat of the song? How accurate is their synchronisation with the musical beat? Do mothers/infants synchronise with the musical beat similarly, i.e., in amount and accuracy, at different infant ages and with respect to the presence or absence of physical contact? Does the musical tempo of the songs affect mothers'/infants' synchronisation with the musical beat? With which beats do mothers/infants synchronise more often? Is the mothers'/infants' synchronisation with the musical beat related to the phrasing structure of the song? In particular, in Chapter 4 the partners of the dyad were found to participate in the phrases of the song as a function of the musical tempo. Will there be a similar pattern here when they synchronise with the beat? On the other hand, in Chapter 3 my findings suggested that when the mothers sing to their infants they extend certain beats over others. Will there be a similar metrical structure of the song when mothers synchronise with the musical beat? How do infants synchronise with the beat in relation to the metrical structure emphasised by the mothers through their singing and synchronous behaviours? Which kind of behaviours, i.e., single gestures, cyclical actions or communicative-affective behaviours, do mothers/infants synchronise the most with the musical beat? Which part of the body do mothers/infants use the most when synchronising with the musical beat?

Hypotheses about the mother:

Mothers are predicted to co-ordinate their behaviours with the beat in order to convey a coherent and temporally organised participation to their infants and that their accuracy will involve an anticipation over the beat of 20 to 50ms, as suggested by Pouthas (1996). Mothers are expected to show similar amounts of behaviour in synchrony with the musical beat of the songs and similar accuracy, independently of context and age. It is anticipated that the mother will synchronise with the musical beat similarly in both the no-touch and touch contexts as well as at both 3-4months and 7-8-months. Regarding the mothers' synchronisation with the beat and the musical tempo of the songs, no particular prediction is made. If the mother were stressing this metrical information, extending the duration of the relevant beats while singing, then I predict that the mother would also emphasise them by displaying synchronisation with their behaviours. It is anticipated that the mother will produce synchronous behaviours evenly distributed across each phrase of the song without great variation, in order to stress the temporal structure of the song. The mother is predicted to synchronise with the beat mostly through her cyclical activity. Moreover, I expect that the mother will mainly synchronise with actions of her own body when the infant is 3-4 months

old, whereas at 7-8 months the mother will produce more synchronous behaviours in contact with the infant's body, in order to avoid over-stimulation of the infant and to maintain his homeostatic state.

Hypotheses about the infant:

Infants are predicted to show synchronous behaviours with the musical beat. However, infants are expected to produce more synchronous and precise behaviours with the beat at 7-8 months of age compared to 3-4 months. At 3-4 months of age, infants are predicted to show no difference when synchronising with the beat during the no-touch and touch contexts. In other words, I expect an effect of age but not of context. No prediction is made in relation to the musical tempo of the songs and the infants' synchronisation with the beat. Regarding the infant's synchrony and the temporal structure of the song, I hypothesise that infants will show some understanding of the temporal structure of the song only when they are 7-8 months of age, synchronising the beats emphasised by the mother, and especially with the downbeats. In relation to the phrases of the song, I predict that infants will show more variation than their mothers. In particular, a relation is hypothesised between the infant's activity level in the phrases of the song and his synchronous behaviours. Infants are expected to show no difference in kind of synchronous behaviours at 3-4 months in relation to physical contact. However, in my view they will show more cyclical actions in synchrony with the musical beat at 7-8 months compared to 3-4 months because of the development of their motor system and stronger muscles. Regarding the part of the body infants will use the most when synchronising with the musical beat, I predict that they will use different parts of their body at 3-4 months to synchronise with the beat, and that physical contact will not play a role. At 7-8 months, infants are predicted to use their limbs, following Moog's (1976) argument that while in the early months of life infants show diffuse synchronous actions, towards the end of the first year of life their synchronous behaviours will be more concentrated in their limbs.

In order to test these hypotheses, use was made of the dataset of interaction based around songs presented in Chapter 3, section 3.1.2. Mothers were asked to sing songs to their 3-4-months-old infants during no-touch and touch contexts, and to their 7-8-months old infants during a touch context. The analyses then proceed as follows. First of all, synchronous behaviours (physical and communicative-affective) with the musical beat are assessed, comparing the onsets of events to determine whether there is synchronisation, i.e., whether the onset time of a behaviour and the beat occur within 40ms (i.e., 0ms to 40ms) and 80ms

(i.e., 0ms to 80ms) temporal windows. The overall amount of behaviours synchronous with the beat is measured in relation to the overall participation of the partner in the interaction. Next, mean distance between onsets of synchronous behaviours and the beat are measured to calculate accuracy. The relation between the overall mean number of synchronous behaviours and beat position is examined, as well as that between the overall mean number of synchronous behaviours and phrases of the song. Finally, the kind and category of synchronous behaviours performed by each partner are measured.

However, it needs to be noted that self-synchrony and synchrony with the musical beat are assessed differently. In fact, in the case of synchrony with the beat there is a clear objective reference point which is the beat and the synchronous behaviour with the beat occurs either before, on or after it. By contrast, self-synchrony is necessarily more arbitrary and a temporal reference is used to determine it, i.e., the chronological order in which the behaviours occur and the distance between them. Hence the 'previous behaviour' becomes the reference for self-synchrony. For instance, there is self-synchrony between two behaviours when they either occur at the same time, i.e., 0ms distance, or very closed to each other, i.e., at 40ms or 80ms latency. However, self-synchrony might occur between more than two behaviours. For instance, it could happen between three behaviours where the distance between the first two behaviours is 40ms and the distance between the 2nd and 3rd behaviours is 80ms. In this case there is a 'burst' of self-synchronous behaviours where there is no 'direct' self-synchrony between the 1st and 3rd behaviours.

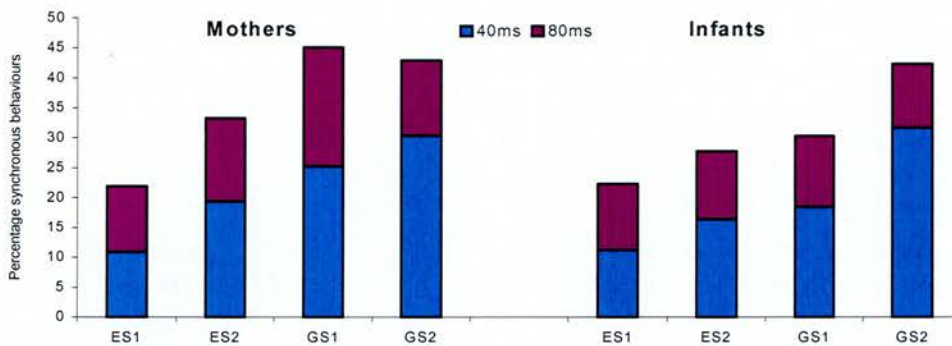
Another important aspect is that although synchrony with the musical beat and self-synchrony are assessed in different ways they are not mutually exclusive. For example, one partner might move in self-synchrony in order to synchronise with the beat, or he/she might co-ordinate his/her own behaviours independently of the external musical beat but on the bases of an internal pace. Or it could be that the partner synchronises some behaviours with the beat and others in self-synchrony.

5.2.1 Analysis of mothers' and infants' synchrony with the musical beat

In this section, mothers' and infants' synchronisation with the musical beat is examined. Detailed explanation of the analysis procedure for mothers' and infants' synchronisation with the musical beat is described in Chapter 2, section 2.3.2.2. However, there is synchronisation when the distance between the onsets of the partners' behaviours and the onsets of the musical beat is either within 40ms or 80ms temporal windows. The focus of the

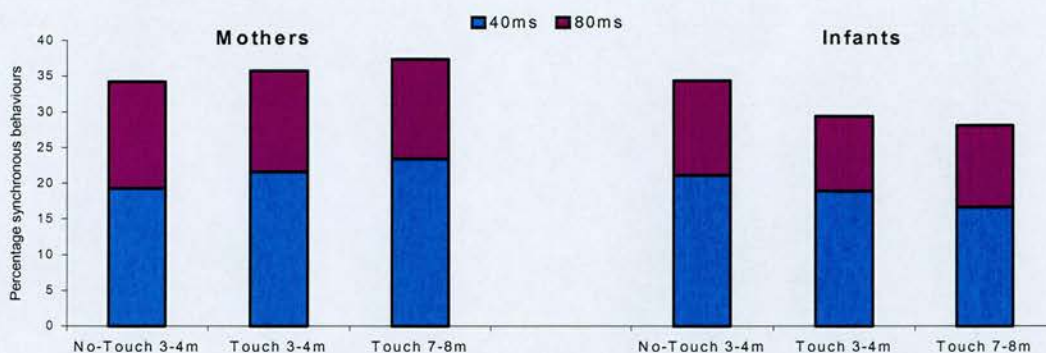
present section is on: a) the overall amount of behaviours in synchrony with the beat, expressed as a percentage of the overall amount of behaviours produced in the interaction; b) the mean distance between the onset time of behaviours and musical beats, at 40ms and 80ms latencies (the lower the score the better the accuracy with the beat); c) the percentage of synchronous behaviours occurring before, on and after the beat; d) Chi square analysis to assess whether there is a significant effect of mother and infant synchronisation with the beat; e) synchronisation with the musical beat and its relation with the phrase of the song and the beat position; f) kind and category of behaviours that partners synchronise with the musical beat.

Figure 5.5 Percentage of mothers' and infants' behaviours in synchrony with the beat, as a function of dyad, collapsed across conditions



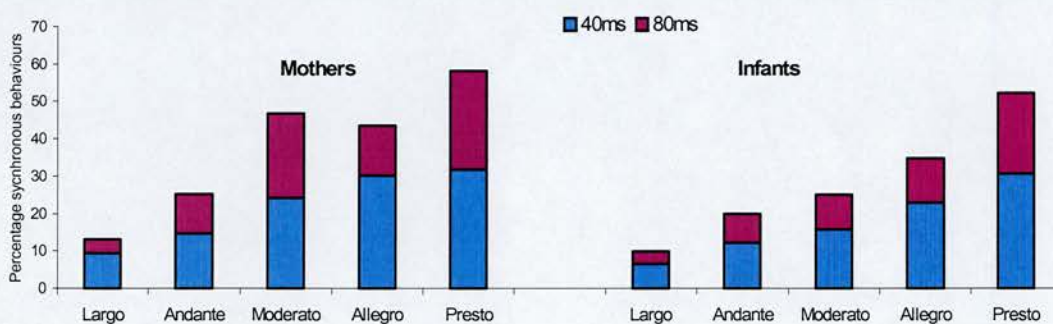
Overall mothers appear to produce slightly more behaviours in synchrony with the beat compared to their infants, as shown in Figure 5.5. More interestingly both partners of the dyad perform the majority of behaviours in synchrony with the musical beat at 40ms latency than 80ms latency. Among mothers, the GS mothers produce a high percentage of actions in synchrony with the beat. With respect to infants, the GS2 infant performs the majority of behaviours in synchrony with the beat. Both partners of the ES1 dyad produce the least amount of synchronous behaviours with the beat.

Figure 5.6 Percentage of mothers' and infants' behaviours in synchrony with the beat, as a function of context and age



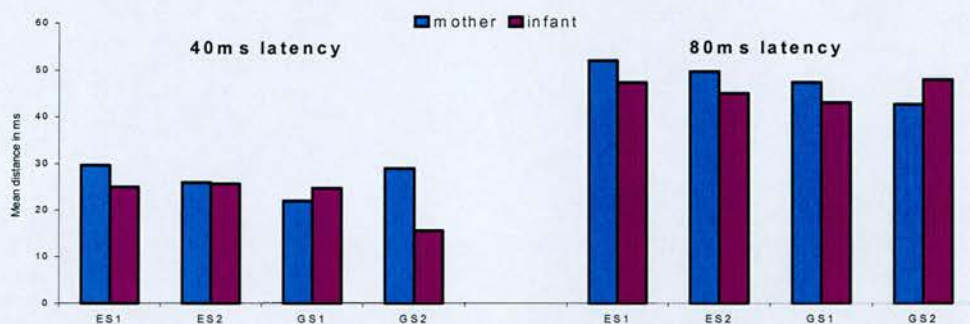
As Figure 5.6 shows, overall mothers appear to perform slightly more synchronous behaviours with the beat than their infants especially in relation to age. However, it is interesting to observe that mothers produce a similar percentage of behaviours synchronous with the beat independently of context or age. On the other hand, infants produce more behaviours in synchrony with the beat in the no-touch context compared to the touch context. However, when age is considered infants do not show difference in the amount of behaviours matching the beat they produce at 7-8 months and 3-4 months.

Figure 5.7 Percentage of mothers' and infants' behaviours in synchrony with the beat, as a function of musical tempo



Mothers' and infants' amount of synchronous behaviours with the musical beat appear also to be related to the musical tempos of the songs (see Figure 5.7). In fact, the faster the song the higher the percentage of synchronous behaviours the partners perform, although during the *allegro* tempo the mothers synchronise less often compared to *moderato*. For instance, both mothers and infants appear to produce the majority of their synchronous behaviours with the beat during songs at the *presto* tempo and the least during the *largo* tempo songs.

Figure 5.8 Accuracy of mothers' and infants' synchronous behaviours with the beat (mean distances between synchronous behaviours), as a function of dyad



From Figure 5.8 it appears that mothers and infants display similar accuracy when synchronising with the musical beat at both latencies. There are some small differences. For instance, at 40ms latency, the GS1 mother seems to be more accurate when matching the musical beat compared to the others, whereas at 80ms latency it is the GS2 mother who appears more precise than the others. By contrast, at 40ms latency the GS2 infant displays high accuracy not only compared to the other infants but also compared to the mothers. However, at 80ms latency it is the GS1 infant who is slightly more accurate than the other infants.

Figure 5.9 Accuracy of mothers' and infants' synchronous behaviours with the beat (mean distances between synchronous behaviours), as a function of context and age

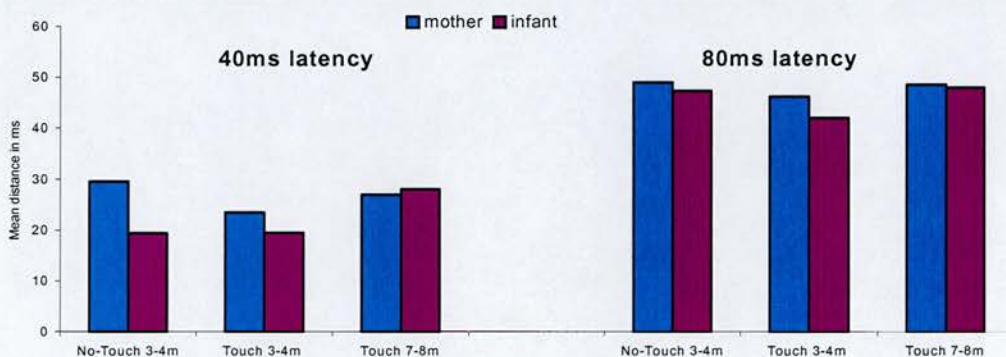
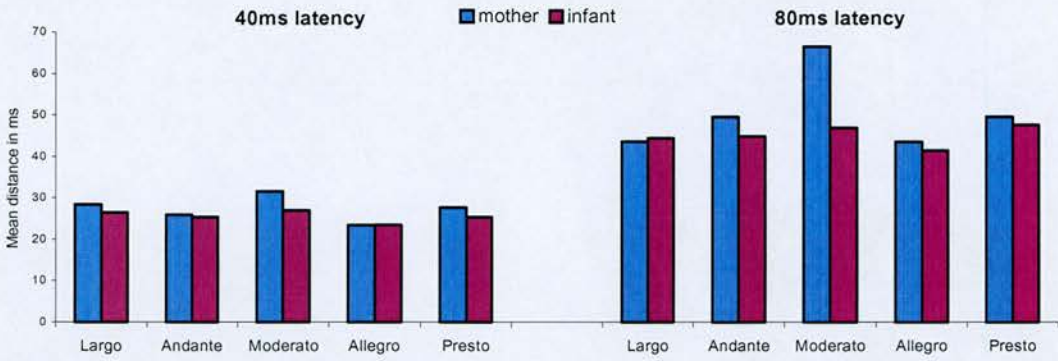


Figure 5.9 suggests that mothers are much less precise with the musical beat during the no-touch context than the touch one, and that this holds at both latencies. Moreover, at both the 40ms and 80ms temporal windows mothers display little accuracy with the beat at 7-8 months compared to 3-4 months. On the other hand, at 40ms latency infants do not show any difference in accuracy as a function of context, whereas at 80ms latency they seem slightly more accurate in the touch context. Finally, infants appear to be less precise with the musical beat at 7-8 months compared to 3-4 months, at both latencies.

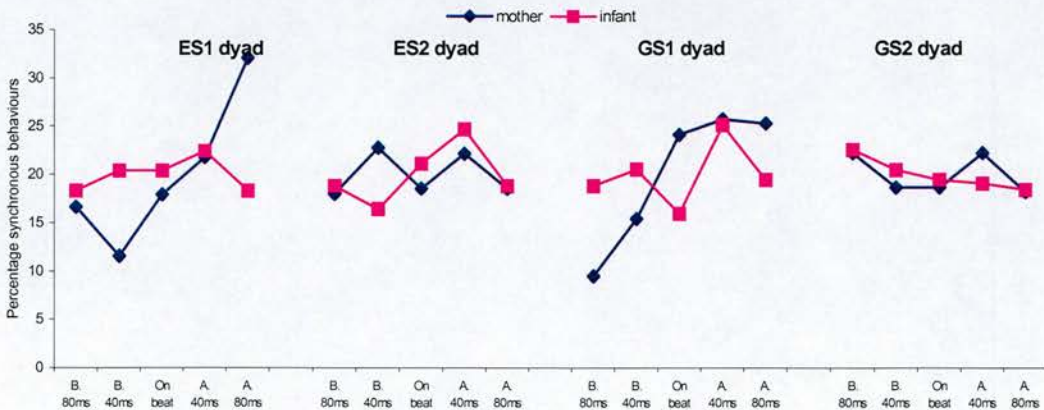
Figure 5.10 Accuracy of mothers' and infants' synchronous behaviours with the beat (mean distances between synchronous behaviours), as a function of musical tempo



As Figure 5.10 shows, overall mothers and infants display a similar level of accuracy when they synchronise with the beat in relation to the musical tempo of the songs. However, during the *moderato* tempo mothers seem to be less precise with the beat compared to the other tempos, especially at 80ms latency.

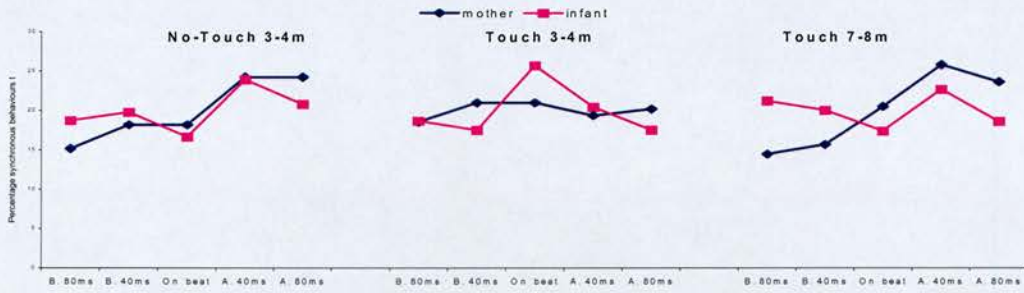
Thus far, I discussed how accurate mothers and infants are when they synchronise with the musical beat. However, another aspect closely related to accuracy is the region on which the synchronous behaviours fall. So each partner could synchronise before, after or exactly on the beat. Figures 5.11 to 5.13 plot the percentage of the mothers' and infants' behaviours in synchrony with the beat, according to the area on which they synchronise mostly, i.e., 80ms or 40ms before the beat, exactly on the beat, 40ms and 80ms after the beat.

Figure 5.11 Mothers' and infants' percentage of synchronous behaviours before, on and after the beat, as a function of dyad, collapsed across conditions



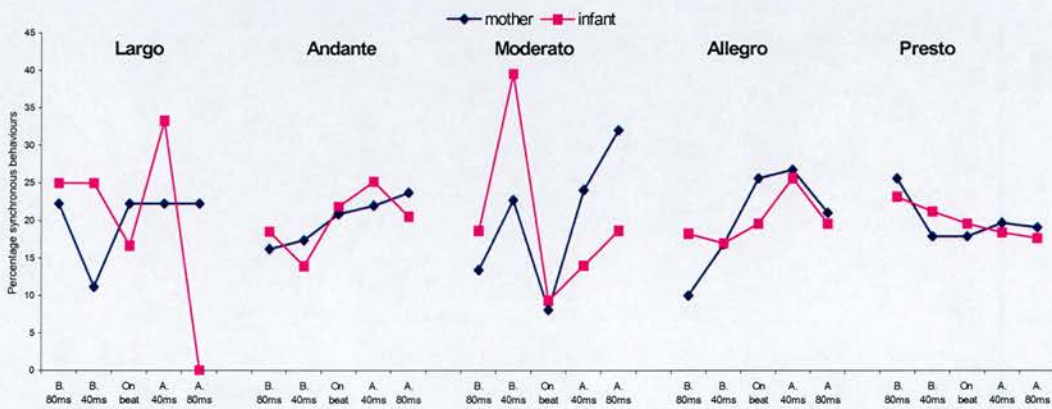
As indicated by Figure 5.11, overall mothers and infants seem to synchronise more often 40ms after the musical beat. However, there are some individual differences. For instance the ES1 mother synchronises more frequently 80ms after the beat. By contrast, both partners of the GS2 dyad match often 80ms before the beat. The ES2 mother shows a mixed pattern, matching with the beat both 40ms before and 40ms after the beat.

Figure 5.12 Mothers' and infants' percentage of synchronous behaviours before, on and after the beat, as a function of context and age



As Figure 5.12 shows, across the different conditions mothers and infants appear to synchronise more often immediately after the beat at 40ms latency. However, it is interesting to note that in the touch context at 3-4 months infants often synchronise exactly on the beat, and at 7-8 months they often synchronise 80ms before the beat.

Figure 5.13 Mothers' and infants' percentage of synchronous behaviours before, on and after the beat, as a function of musical tempo



As Figure 5.13 shows, mothers and infants synchronise with some tempos more frequently after the beat, e.g., the *andante* and *allegro* tempos, and with others before the beat, e.g., the *presto* tempo. On the other hand, during the *largo* and *moderato* tempos, the partners of the dyad synchronise differently. In fact, during the *largo* tempo infants never synchronise 80ms after the beat, but they often do so at 40ms after the beat. By contrast, mothers match less

often 40ms before the beat at the *largo* tempo. With *moderato* tempo songs infants synchronise frequently 40ms before the beat, whereas for mothers it occurs 80ms after the beat.

5.2.2 Is mother/infant synchrony with the musical beat simply an artefact?

To assess whether mothers' and infants' participation is significantly in synchrony with the musical beat, Chi square tests were applied. Chi square is a significance test which evaluates the relation between an observed frequency distribution and an expected frequency distribution. In this case, the expected value is calculated on the assumption that behaviours are distributed randomly across the duration of the song and therefore that they will be evenly distributed. A behaviour is considered to be in synchrony when it falls on a temporal window centred on the beat. Two different sizes of temporal windows are considered: a window of ± 40 ms, or 120ms, and a larger one of ± 80 ms, or 200ms. In fact, because the beat occurs itself within a 40ms frame the width of the window of synchrony is either 120ms, i.e., 40ms+40ms+40ms, or 200ms, i.e., 80ms+40ms+80ms. However, in this section for convenience sake I will use the shorthand forms 40ms and 80ms latencies. Thus the total interval of synchrony in a song is the number of beats times the length of the window of synchrony. The ratio of this value to the remainder of the overall length of the song can be used to calculate the expected frequencies. The observed values are the total number of behaviours that fall within the windows of synchrony and the total number which do not. If there is a tendency to synchronise, it is expected that a higher number of behaviours will fall within the window of synchrony than would be expected on the random assumption. For each partner, for each song, and for each window of synchrony length, a Chi square test of this type (with one degree of freedom) was calculated.

Table 5.1 shows an example of the Chi square analysis of the extent to which the infant's behaviours are in synchrony with the beat for the ± 40 ms window, whose length is 0.12s. There are 32 beats in the song and their overall duration is 13.58s. The 10 columns in the table represent:

- 1) The infant
- 2) The song, because Chi square is measured on each individual song.
- 3) Observed moves in synchrony with the beat, i.e., the number of movements the infant produces in synchrony with the musical beat, within 40ms before, 40ms on the beat, and 40ms after the beat.

- 4) Observed moves not in synchrony with the beat, i.e., the number of the infant's movements that falls outside the window of synchrony.
- 5) Expected moves in synchrony with the musical beat. The expected values are calculated using the formula: $(\text{Tot Observed moves In synchrony} + \text{Tot Observed moves Not in synchrony}) * (\text{the length of the window of synchrony} * \text{number of beats of the song}) / \text{overall duration of the song}$. The example yields: $(10 + 20) * (0.12s * 32) / 13.58s = 8.48$. This is the expected number of the infant's movements in synchrony with the musical beat, assuming $\pm 40ms$ interval.
- 6) Expected moves Not in synchrony with the musical beat. The expected number of infant's behaviours not in synchrony with the musical beat is calculated on a similar basis. $(\text{Tot Observed moves In synchrony} + \text{Tot Observed moves Not in synchrony}) * (\text{overall duration of the song} - (\text{the length of the window synchrony} * \text{number of beats of the song})) / \text{overall duration of the song}$. The example yields $(10 + 20) * (13.58s - (0.12s * 32)) / 13.58s = 21.52$.
- 7) Number of beats
- 8) Total beat duration
- 9) Chi square value
- 10) P value

The Chi square test is considered to be significant when p is less than 0.05. Since it is a naturally two-tailed test, it will be sensitive to the effect in either direction, and thus it should be checked that the effect is in the right direction. In the current case, the right direction occurs when the observed moves in synchrony with the beat are more than the expected movements in synchrony with the musical beat. The example yields the following results: the infant's observed movements in synchrony with the beat come to 10, and the expected movements in synchrony with the beat are 8.48. Therefore, since Chi square value (0.38) is not significant ($p = .54$), with one degree of freedom, it can be concluded that the infant does not synchronise significantly with the musical beat. The same procedure was applied to the $\pm 80ms$ window.

Table 5.1 Chi square of the infant's behaviours in synchrony with the musical beat within a temporal window of 40ms

Infant	Song	Observed moves In synchrony	Observed moves Not in synchrony	Expected moves In synchrony	Expected move Not in synchrony	Number beats	Total beat duration	χ^2	p value
ES2	Ally Bally	10	20	8.48	21.52	32	13.58	.38	ns

This method of analysis was applied to all songs sung by the mothers. In the following tables the results of Chi square tests of the mothers' and infants' behaviours in synchrony with the musical beat at 40ms and 80ms latencies are shown. Although Chi square was measured on individual songs for sake of brevity, in the tables the results are grouped in relation to participants, conditions and musical tempos. When the significant effect goes in the opposite direction, i.e., the expected movements are more than the observed ones, the p value is indicated by '*'.

Table 5.2 Chi-square analyses of the infants' behaviours in synchrony with the musical beat as a function of infant, collapsed across conditions

	Infant	Observed moves In synchrony	Observed moves Not in synchrony	Expected moves In synchrony	Expected moves Not in synchrony	Number beats	Tot beat duration	χ^2	p value
40ms latency									
	ES1	28	252	43.08	236.91	208	169.48	6.24	.012*
	ES2	104	477	119.61	461.39	351	205.52	2.57	ns
	GS1	107	507	143.69	470.31	286	148.30	12.23	.000*
	GS2	172	446	196	422	416	152.61	4.30	.038*
80ms latency									
	ES1	47	233	71.81	208.19	208	196.48	11.53	.000*
	ES2	170	411	199.35	381.65	351	205.52	6.58	.010*
	GS1	176	438	239.47	374.52	286	148.30	27.58	.000*
	GS2	291	327	328.16	289.84	416	152.61	8.97	.003*

When the 40ms temporal window is considered, aside from the ES2 infant, the rest of the infants show a significant effect of synchrony with the musical beat although in the opposite direction than would be expected. At 80ms latency, all the infants display a significant effect with the beat but in the opposite direction.

Table 5.3 Chi-square analyses of the mothers' behaviours in synchrony with the musical beat as a function of mother, collapsed across conditions

	Mother	Observed moves In synchrony	Observed moves Not in synchrony	Expected moves In synchrony	Expected moves Not in synchrony	Number beats	Tot beat duration	χ^2	p value
40ms latency									
	ES1	42	392	70.57	363.43	208	169.48	13.81	.000*
	ES2	107	368	101.15	373.85	351	205.52	.43	ns
	GS1	161	375	120.07	415.93	286	148.30	17.98	.000
	GS2	118	343	133.42	327.57	416	152.61	2.51	ns
80ms latency									
	ES1	82	353	117.81	317.19	208	169.48	14.93	.000*
	ES2	170	305	168.58	306.42	351	205.52	.02	ns
	GS1	245	291	200.12	335.88	286	148.30	16.06	.000
	GS2	198	263	226.37	234.62	416	152.61	6.99	.008*

At both latencies only the GS1 mother synchronises significantly with the beat, whereas the ES2 mother does not show any significant effect. On the other hand, the ES1 mother shows a significant effect in the opposite direction at both temporal windows. The GS2 mother, by

contrast, does not show any significant effect at 40ms latency, but with the wider temporal window she performs significantly less behaviours in synchrony with the beat than expected.

Table 5.4 Chi-square analyses of the mothers' and infants' behaviours in synchrony with the musical beat, as a function of context and age (40ms latency)

Condition	Observed moves In synchrony	Observed moves Not in synchrony	Expected moves In synchrony	Expected moves Not in synchrony	Number beats	Tot beat duration	χ^2	p value
Mother								
No-Touch 3-4m	21	82	23.60	79.40	176	99.65	.37	ns
Touch 3-4 m	154	576	164.87	566.96	444	237.82	.86	ns
Touch 7-8m	253	820	236.51	836.49	641	345.44	1.47	ns
Infant								
No-Touch 3-4m	57	242	69.34	229.66	176	99.65	2.86	ns
Touch 3-4 m	106	453	127.22	432.58	444	237.82	4.50	.033*
Touch 7-8m	248	987	304.83	930.17	641	345.44	14.06	.000*

At 40ms latency, during the no-touch context neither of the partners synchronise significantly with the beat. However, in both touch contexts the mothers do not synchronise significantly with the beat whereas the infants display a significant effect in the opposite direction, i.e., the amount of expected behaviours in synchrony with the beat is significantly higher than the amount of observed behaviours.

Table 5.5 Chi-square analyses of the mothers' and infants' behaviours in synchrony with the musical beat, as a function of context of age (80ms latency)

Condition	Observed moves In synchrony	Observed moves Not in synchrony	Expected moves In synchrony	Expected moves Not in synchrony	Number beats	Tot beat duration	χ^2	p value
Mother								
No-Touch 3-4m	34	69	39.33	63.67	176	99.65	1.17	ns
Touch 3-4 m	253	477	279.17	450.82	444	237.82	3.97	.046*
Touch 7-8m	408	666	394.37	679.62	641	345.44	.74	ns
Infant								
No-Touch 3-4m	96	203	115.57	183.43	176	99.65	5.40	.020*
Touch 3-4 m	169	390	215.19	343.81	444	237.82	16.12	.000*
Touch 7-8m	419	816	508.04	726.95	641	345.44	26.51	.000*

When a wider window is considered, i.e., 80ms, mothers still do not synchronise significantly with the beat in any of the conditions. However, in the touch context at 3-4 months mothers produce significantly less behaviours than would be expected in order to synchronise with the beat. On the other hand, the infants show a significant effect of synchrony with the beat but in the opposite direction in all of the conditions.

Table 5.6 Chi-square analyses of the mothers' and infants' behaviours in synchrony with the musical beat, as a function of musical tempo (40ms latency)

	Musical tempo	Observed moves In synchrony	Observed moves Not in synchrony	Expected moves In synchrony	Expected moves Not in synchrony	Number beats	Tot beat duration	χ^2	p value
Mother	Largo	11	134	16.04	128.96	80	87.87	1.78	ns
	Andante	106	651	131.37	625.63	375	274.03	5.93	.015*
	Moderato	35	107	30.43	111.57	51	28.77	.87	ns
	Allegro	183	394	150.84	426.16	403	180.77	9.28	.002
	Presto	93	192	98.94	186.06	320	111.47	.55	ns
Infant	Largo	8	133	15.28	125.72	80	87.87	3.89	.049*
	Andante	91	603	125.22	568.78	375	274.03	11.41	.000*
	Moderato	27	133	33.79	126.21	51	28.77	1.73	ns
	Allegro	136	477	166.41	446.58	403	180.77	7.63	.005*
	Presto	149	336	162.58	322.42	320	111.47	1.70	ns

When the musical tempo of the songs is considered, both partners show significant effect of synchronisation with the beat during *andante* tempo, although in the opposite direction than predicted. Also with *allegro* tempo both partners display a significant effect of synchrony with the beat. However, the infants show significant effect in the opposite direction than predicted. With *largo* tempo songs only the infants show a significant effect but again in the opposite direction.

Table 5.6 Chi-square analyses of the mothers' and infants' behaviours in synchrony with the musical beat, as a function of musical tempo (80ms latency)

	Musical tempo	Observed moves In synchrony	Observed moves Not in synchrony	Expected moves In synchrony	Expected moves Not in synchrony	Number beats	Tot beat duration	χ^2	p value
Mother	Largo	19	127	26.92	119.08	80	87.87	2.86	ns
	Andante	176	581	218.95	538.05	375	274.03	11.85	.000*
	Moderato	65	77	50.72	91.28	51	28.77	6.26	.012
	Allegro	267	310	251.40	325.60	403	180.77	1.72	ns
	Presto	168	117	164.90	120.10	320	111.47	.14	ns
Infant	Largo	12	129	25.46	115.53	80	87.87	8.69	.003*
	Andante	151	543	208.70	485.30	375	274.03	22.81	.000*
	Moderato	44	116	56.21	103.69	51	28.77	4.15	.041*
	Allegro	226	387	277.36	335.64	403	180.77	17.37	.000*
	Presto	251	234	270.96	214.04	320	111.47	3.33	ns

When a larger temporal window is considered, mothers synchronise significantly with the beat only during *moderato* tempo songs. With *andante* tempo songs they also show a significant effect with the beat but in the opposite direction. On the other hand, infants produce significantly less behaviours in synchrony with the beat than would be expected with all tempos of the songs except *presto*.

5.2.3 Mothers' and infants' synchrony with the beat across the phrases of the song

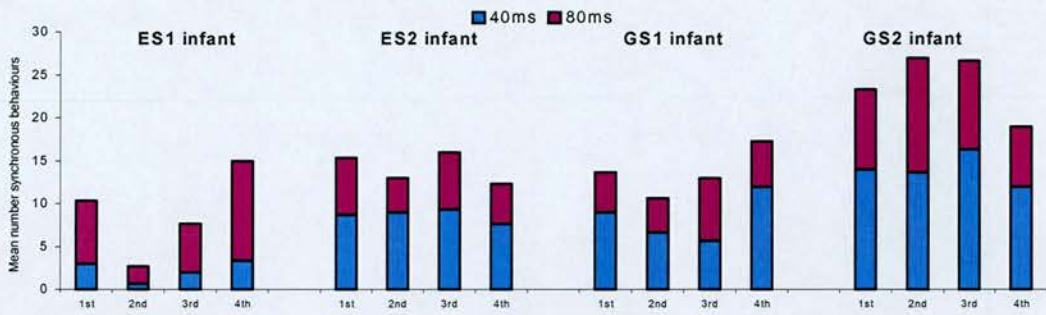
In Chapter 4 on the physical participation of the partners, it emerged that mothers and infants show a different level of activity across the phrases of the songs. Does the same hold when the partners of the dyad synchronise with the musical beat? This section examines whether the partners of the dyad synchronise more often with the beat in certain phrases rather than others as a function of dyad (Figures 5.14 and 5.15), as a function of context and age (Figure 5.16), and as a function of musical tempo of the songs (Figures 5.17 and 5.18).

Figure 5.14 Overall mean number of mothers' behaviours in synchrony with the musical beat for each phrase, as a function of mother



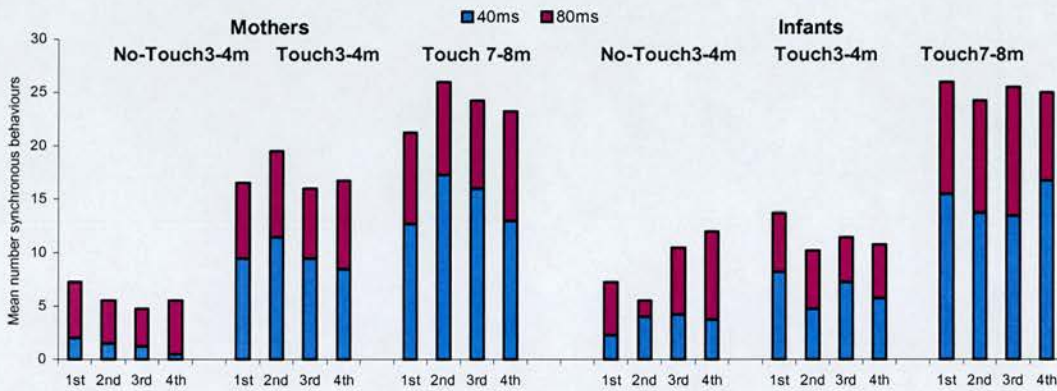
As Figure 5.14 suggests, overall mothers tend to show substantial individual differences in how they synchronise with the beat across the phrases of the songs. However, it is the GS1 and ES2 mothers who appear to synchronise more often in the 2nd phrase of the song compared to the others. On the other hand, the ES1 and GS2 mothers display a more even distribution of synchronous behaviours across the phrases of the song, although in the 3rd phrase they both show some variation.

Figure 5.15 Overall mean number of infants' behaviours in synchrony with the musical beat for each phrase, as a function of infant



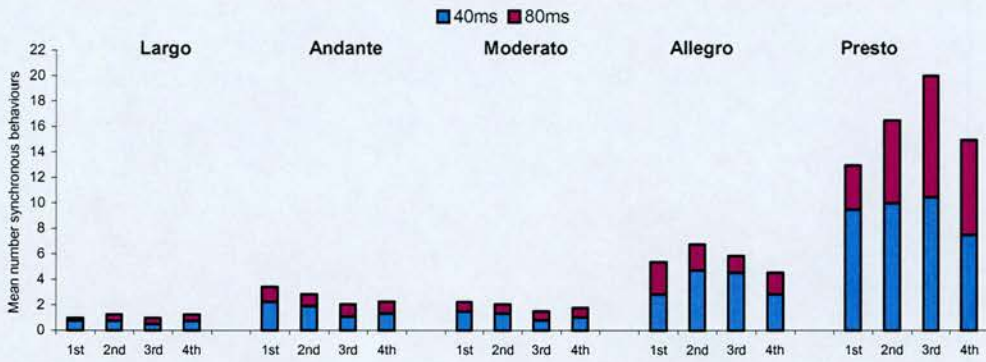
Overall infants display several variations when they synchronise with the musical beat across the phrases of the songs. In fact, the ES1 and GS1 infants show a tendency to synchronising more frequently in the 4th phrase. By contrast, the ES2 and GS2 infants seem to match the beat less often in the 4th phrase of the song.

Figure 5.16 Overall mean number of mothers' behaviours in synchrony with the musical beat for each phrase, as a function of context and age



When context and age are considered, as Figure 5.16 shows, mothers and infants display great variation in the mean number of synchronous behaviours with the beat across the phrases of the song. However, both partners display a number of patterns. For instance, mothers appear to synchronise more often with the musical beat in the 1st phrase of the songs during the no-touch context at 3-4 months, and in the 2nd phrase of the songs in the conditions related to age. On the other hand, in the no-touch context, infants produce the majority of their synchronous actions with the beat in the 4th phrase but only at 80ms latency. Moreover, at 80ms latency, at 3-4 months as well as at 7-8 months infants synchronise more frequently with the beat in the 1st phrase of the song. Later, in section 5.2.4 (Figures 5.21 and 5.22), I will present the statistical analysis regarding the mothers' and infants' synchronous behaviours in the phrases of the song together with the analysis of the metrical structure.

Figure 5.17 Overall mean number of mothers' behaviours in synchrony with the musical beat for each phrase, as a function of musical tempo

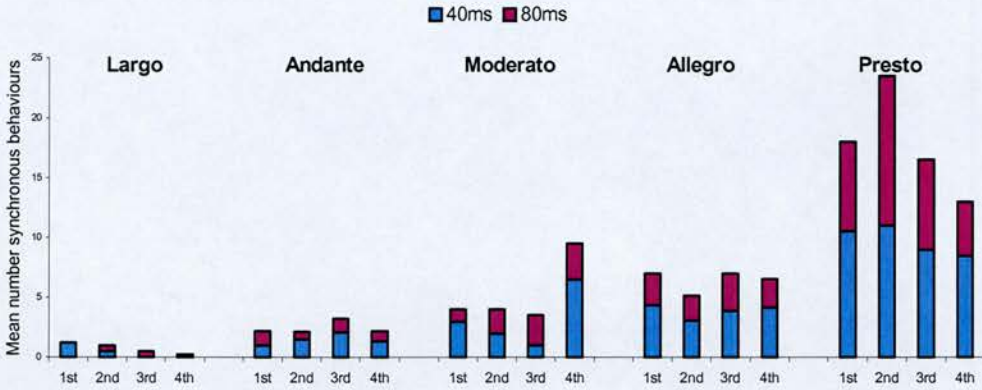


It is interesting to note in Figure 5.17 the contrast in the mothers' mean number of synchronous behaviours with the beat during slow and fast tempos songs. Two two-way mixed ANOVAs (one for 40ms latency and one for 80ms latency) were used to examine the effect of phrase and of the musical tempo of the song on the number of mothers' synchronous behaviours with the beat. Two factors were considered: a within factor, phrase (x4 levels, i.e., the number of phrases in the song) and a between factor, musical tempo (x5 levels, i.e., *largo*, *andante*, *moderato*, *allegro*, and *presto*). The analysis of variance was carried out on the number of the mothers' behaviours in synchrony with the beat in the phrases of all song performances for each musical tempo. Greenhouse-Geisser p values were used if the assumption of sphericity was not satisfied.

Although mothers display no significant effect of phrase, they show a main effect of musical tempo at 40ms latency ($F(4, 31) = 9.89, p = .00001$) and at 80ms latency ($F(4, 31) = 29.04, p = .00001$). For both latencies, the mothers' mean number of behaviours in synchrony with the beat is considerably higher for the *presto* tempo (9.37 at 40ms latency and 16.12 at 80ms latency) than for any of the other tempos (*moderato*: 4.37 at 40ms and 8 at 80ms; *allegro*: 3.73 at 40ms and 5.63 at 80ms; *andante*: 1.63 at 40ms and 2.65 at 80ms; *largo*: 0.69 at 40ms and 1.12 at 80ms). Mothers show a significant interaction between musical tempo and phrases of the songs. This interaction is clearer at 80ms latency. At 40ms latency mothers show a trend towards significance regarding the interaction between the effects of phrase position and musical tempo on the frequency of their synchronous behaviours (40ms latency, $F(12, 93) = 1.74, p = .093$), whereas at 80ms latency they show a significant interaction ($F(12, 93) = 2.90, p = .009$). This suggests that there is variation across tempos in how phrase position affects the number of behaviours that the mothers produce in synchrony with the beat. For instance, data in Figure 5.17 indicate that the mothers seem to synchronise most

often with the musical beat in the 2nd phrase of the song during the *allegro* tempo, and in the 1st phrase with the *andante* tempo.

Figure 5.18 Overall mean number of infants' behaviours in synchrony with the beat for each phrase, as a function of musical tempo



As Figure 5.18 shows, the way the infants' behaviours in synchrony with the beat are distributed across the phrases of the song varies in relation to the musical tempo. As in the analysis of the mothers' data, two two-way mixed ANOVAs (one for 40ms latency and another for 80ms latency) were used to measure the effect of phrase and of tempo on the number of behaviours infants produce in synchrony with the beat. The analysis of variance included two factors: one within factor, phrase (x4 levels, i.e., the number of phrases in the song) and one between factor, musical tempo (x5 levels, i.e., *largo*, *andante*, *moderato*, *allegro*, and *presto*). The analysis of variance was carried out on the number of the infants' behaviours in synchrony with the beat in the phrases of all song performances in every musical tempo.

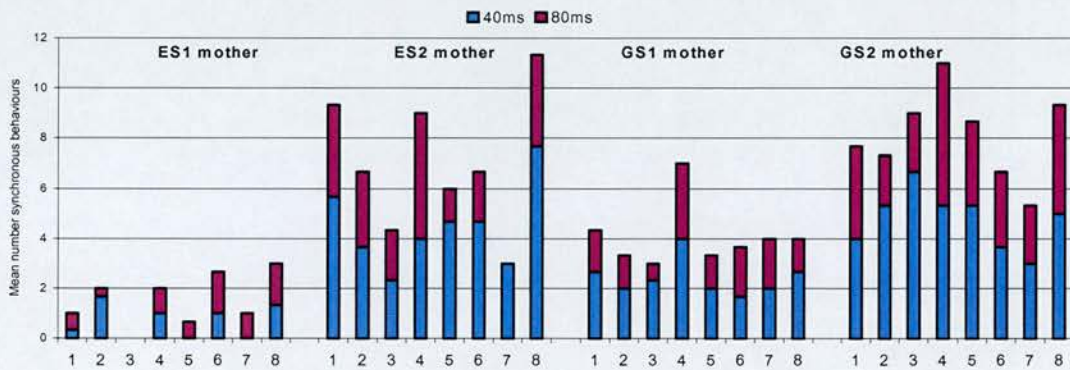
Similarly to their mothers, infants do not show a main effect of phrase but they show a significant main effect of musical tempo at 40ms latency ($F(4, 31) = 23.81, p = .0001$) and at 80ms latency ($F(4, 31) = 27.01, p = .0001$). In fact, the mean number of behaviours they produce in synchrony with the musical beat is considerably higher for the *presto* tempo (9.75 at 40ms and 17.75 at 80ms) compared to the other tempos (*allegro*: 3.86 at 40ms and 6.42 at 80ms; *moderato*: 3.12 at 40ms and 5.25 at 80ms; *andante*: 1.47 at 40ms and 2.43 at 80ms; *largo*: 0.50 at 40ms and 0.75 at 80ms). Also, there is a significant interaction between phrases and musical tempo at both latencies (40ms latency, $F(12, 93) = 2.09, p = .025$; 80ms latency, $F(12, 93) = 2.46, p = .008$). Therefore, the way infants distribute their behaviours in synchrony with the beat across the phrases of the songs appears to be influenced by the

musical tempo of the songs. For instance, during the *andante* tempo infants synchronise more often with the beat in the 3rd phrase of the song, and with the *allegro* tempo they match least often the beat in the 2nd phrase of the song.

5.2.4 Mothers’ and infants’ synchrony with beat in relation to its position (and the metrical structure)

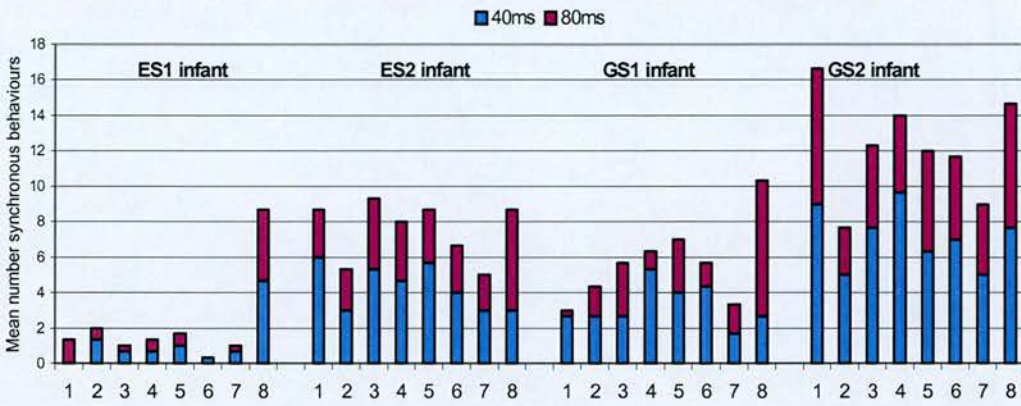
In Chapter 3, among other aspects, I examined which beats mothers extend when singing to their infants. Here the focus is on the beats that mothers and infants synchronise more frequently through their behaviours. As with Chapter 3, when the analysis refers to the musical beats, the 8-beat phrase structure is considered. Figures 5.19 and 5.20 plot the overall mean number of behaviours in synchrony with the beat that mothers and infants produce as a function of beat position and dyad. Figures 5.21 and 5.22 present the partners’ overall mean number of synchronous behaviours as a function of beat position and condition.

Figure 5.19 Overall mean number of mothers’ synchronous behaviours with the musical beat, as a function of beat position and mother



Although mothers appear to synchronise with almost every beat of the phrase of the song, as Figure 5.19 shows, they tend to match some beats more often than others, especially at 80ms latency. For instance, at 80ms latency, both the GS mothers synchronise more often with the 4th beat of the phrase, and the ES2 mother with the 8th, 1st and 4th beats. By contrast, the ES1 mother not only synchronises with the beat less often overall compared to the other mothers, but she also never matches the 3rd beat of the phrase.

Figure 5.20 Overall mean number of infants' synchronous behaviours with the musical beat, as a function of beat position and infant



As Figure 5.20 shows, infants synchronise with every beat of the phrase. However, they also display some interesting patterns. For instance, at 80ms latency the ES1 and GS1 infants synchronise their behaviours more frequently with the 8th beat. The GS1 infant also synchronises often with the 5th beat. The ES2 infant matches mostly the 3rd beat, and also the 1st, 5th and 8th beats, whereas the GS2 infant synchronises frequently the 1st beat as well as with the 4th and 8th beats.

Figure 5.21 Overall mean number of mothers' synchronous behaviours with the musical beat, as a function of beat position and condition

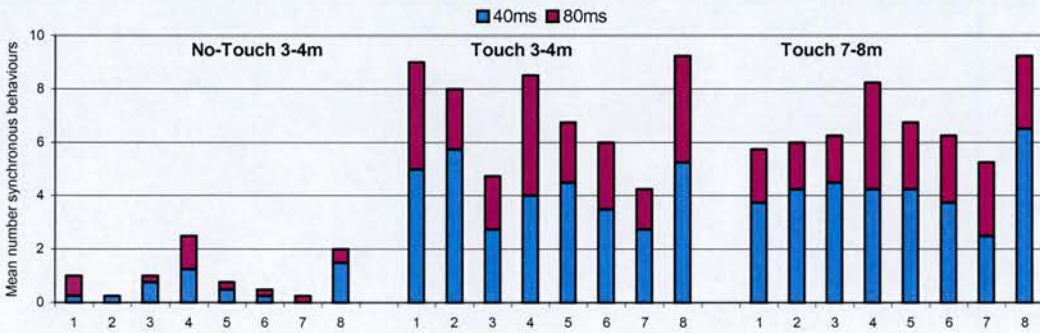


Figure 5.21 shows that across conditions, and especially at 80ms latency, the mothers tend to synchronise more often with the 4th and 8th beats. However, in the touch context at 3-4 months mothers also tend to synchronise often with other beats, in particular the 1st and 2nd beats of the phrase. This holds at both latencies.

Table 5.7 Mothers' mean number of synchronous behaviours with the beat, as a function of position, type, pair and phrase

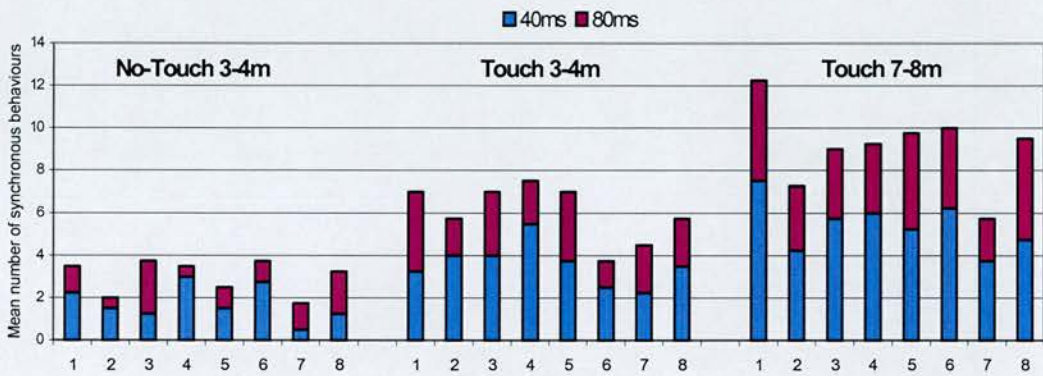
Beat position	Mean number synchronous behaviours		Type of beat	Mean number synchronous behaviours		Pair	Mean number synchronous behaviours		Phrase	Mean number synchronous behaviours	
	40ms	80ms		40ms	80ms		40ms	80ms		40ms	80ms
1 st	0.28	0.49	Downbeat	0.25	0.40	1 st (1 st + 2 nd beats)	0.30	0.47	1 st	0.28	0.45
2 nd	0.32	0.44		Upbeat	0.32	0.52	2 nd (3 rd + 4 th beats)	0.27	0.49	2 nd	0.36
3 rd	0.25	0.37					3 rd (5 th + 6 th beats)	0.26	0.42	3 rd	0.29
4 th	0.30	0.60				4 th (7 th + 8 th beats)	0.29	0.47	4 th	0.23	0.42
5 th	0.29	0.44									
6 th	0.23	0.40									
7 th	0.16	0.30									
8 th	0.41	0.64									

In Chapter 3, I examined the effect on beat duration when mothers sing to their infants across different conditions. Here, the same kind of analysis is applied but considering the number of synchronous behaviours that mothers produce when they synchronise with the beat. Two mixed four-way ANOVAs (one for 40ms latency and another for 80ms latency) were employed to investigate the effects of phrase, pair, type of beat and condition on the number of behaviours that the mothers produced in synchrony with the beat. The analysis of variance included three within factors, i.e., phrase (x4 levels, i.e., the number of phrases in the song), pair (x4 levels, i.e., number of pairs in each 8-beat phrase), type of beat, i.e., upbeat/downbeat (x2 levels, i.e., contrast of stronger and weaker beat within each pair), and one between factor, i.e., condition (x3 levels, i.e., no-touch 3-4 months, touch 3-4 months and touch 7-8 months). The analysis of variance was again measured on the mothers' behaviours produced in synchrony with the beat in all song performances for each condition. If the assumption of sphericity was not satisfied, Greenhouse-Geisser p values were used.

First of all, there is no significant main effect of phrase but there is a significant effect of condition at 80ms latency only ($F(2, 29) = 5.02, p = .013$). In fact, the mothers' mean number of behaviours in synchrony with the beat in the no-touch context at 3-4 months is 0.12 (at 40ms latency) and 0.21 (at 80ms latency); in the touch context at 3-4 months it is 0.35 (at 40ms latency) and 0.59 (at 80ms latency); and in the touch context at 7-8 months it is 0.28 (at 40ms latency) and 0.45 (at 80ms latency). There is a highly significant interaction between pair and type of beat, i.e., upbeat/downbeat, at 40ms latency ($F(3, 87) = 4.21, p = .008$) and at 80ms latency ($F(3, 87) = 7.32, p = .00001$). Thus mothers synchronise more often with certain beats according to the pair. Pairwise comparison is used to explore whether those upbeats are related to the same ones as mothers extend when singing, i.e., 4th and 8th beats. Bonferroni correction for multiple comparisons sets the new threshold for significance at $p = .025$. Pairwise comparison shows that the mothers synchronise

significantly more often on the 4th and 8th beats compared to the others at both latencies (t-test 2-tailed (paired) at 40ms latency, 4th and 8th beats combined vs rest of the beats, $t= 2.40$, $df= 32$, $p= .023$; at 80ms latency, 4th and 8th beats combined vs rest of the beats, $t= 3.44$, $df= 32$, $p= .002$). Overall the mothers emphasise the temporal structure of the song through their synchronous behaviours with the beat, again marking the end and the middle parts of the phrase. There is also an interaction between phrase and conditions, which is significant at 80ms latency ($F(6, 87) = 2.38$, $p= .036$), and approaches significance at 40ms latency ($F(6, 87) = 2.15$, $p= .055$). This suggests that mothers match the beats more frequently in certain phrases compared to others and that this varies as a function of condition (see Figure 5.16). At 80ms latency, mothers also show a trend towards significance of an interaction between pair and condition ($F(6, 87) = 2.08$, $p= .063$). This suggests that mothers vary the amount of synchronous behaviours on pairs of beats as a function of condition, as shown in Figure 5.21.

Figure 5.22 Overall mean number of infants' synchronous behaviours with the musical beat, as a function of beat position and condition



In Figure 5.22, it is interesting to note that infants display a different pattern of synchronisation with the beat in relation to age and context. In fact, at both latencies, in the no-touch context at 3-4 months infants synchronise more often on the 4th and 6th beats, whereas in the touch context they match more frequently the 4th beat, and those around it, i.e., 3rd and 5th beats. Finally in the 7-8 months touch context, infants synchronise more often on the 1st beat.

Table 5.8 Infants' mean number of synchronous behaviours with the beat as a function of position, type, pair and phrase

Beat position	Mean number synchronous behaviours		Type of beat	Mean number synchronous behaviours		Pair	Mean number synchronous behaviours		Phrase	Mean number synchronous behaviours	
	40ms	80ms		40ms	80ms		40ms	80ms		40ms	80ms
1 st	0.41	0.71	Downbeat	0.32	0.58	1 st (1 st + 2 nd beats)	0.35	0.59	1 st	0.33	0.56
2 nd	0.30	0.47		Upbeat	0.35	0.55	2 nd (3 rd + 4 th beats)	0.40	0.62	2 nd	0.30
3 rd	0.34	0.62				3 rd (5 th + 6 th beats)	0.34	0.57	3 rd	0.39	0.63
4 th	0.45	0.63				4 th (7 th + 8 th beats)	0.25	0.48	4 th	0.32	0.55
5 th	0.33	0.62									
6 th	0.35	0.54									
7 th	0.20	0.37									
8 th	0.30	0.58									

Two mixed four-way ANOVA (one for 40ms latency and another for 80ms latency) examined the effect of the infants' number of behaviours synchronous with the beat. There were three within factors, i.e., phrase (x4 levels, i.e., the number of the phrases in the song), pair (x4 levels, i.e., number of pairs in each 8-beat phrase), type of beat, i.e., upbeat/downbeat (x2 levels, i.e., contrast of stronger and weaker beat within each pair), and one between factor, i.e., condition (x3 levels, i.e., no-touch 3-4 months, touch 3-4 months and touch 7-8 months). The analysis of variance was carried out on the number of synchronous behaviours with the beats that infants perform across the phrases of all the song performances in each condition. If the assumption of sphericity was not satisfied, Greenhouse-Geisser values were used.

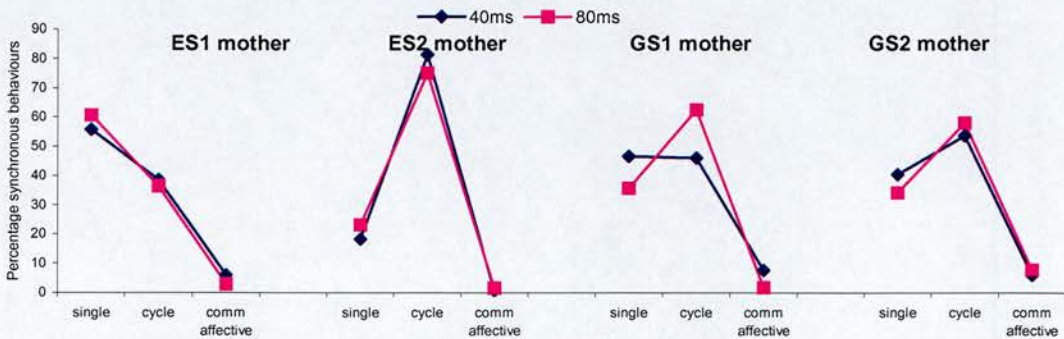
First of all, there is no significant effect of phrase nor of condition at either latency. The infant's mean number of behaviours in synchrony with the beat in the no-touch context at 3-4 months is 0.35 (at 40ms latency) and 0.60 (at 80ms latency); in the touch context at 3-4 months it is 0.30 (at 40ms latency) and 0.50 (at 80ms latency); and in the touch context at 7-8 months it is 0.36 (at 40ms latency) and 0.61 (at 80ms latency). At 40ms latency only, there is a significant effect of pair ($F(3, 84) = 3.65, p = .016$). The data in Table 5.8 suggest that infants match most frequently with the 2nd and 1st pairs. At 80ms latency infants display some significant interactions. There is a significant interaction between phrase, pair and condition ($F(18, 261) = 2.39, p = .002$), which is difficult to interpret. Although the data presented in Figure 5.16 suggest that context may affect the way in which the 3-4-month-old infants' behaviours in synchrony with the beat are distributed across phrases, the two-way interaction between condition and phrase failed to reach significance. There is also a significant interaction between pair and type of beat, i.e., downbeat/upbeat ($F(3, 87) = 3.86, p = .019$). Pairwise comparison shows a significant effect on the 1st, 4th, 5th and 8th beats of the infants' amount of synchronous behaviours (t-tests 2-tailed (paired) 1st, 4th, 5th and 8th

beats combined vs 2nd, 3rd, 6th and 7th beats combined, $t = 2.75$, $df = 32$, $p = .010$). Thus infants not only synchronise significantly more often with the beats stressed by their mothers, but they also synchronise with the main downbeats next to them. Moreover, a significant interaction emerges between phrase, pair and type of beat (downbeat/upbeat) ($F(9, 261) = 2.27$, $p = .037$). This suggests that there is some variation across phrases of the song in the way in which infants synchronise their behaviours with specific beats.

5.2.5 Which of the partners' behaviours are in synchrony with the musical beat?

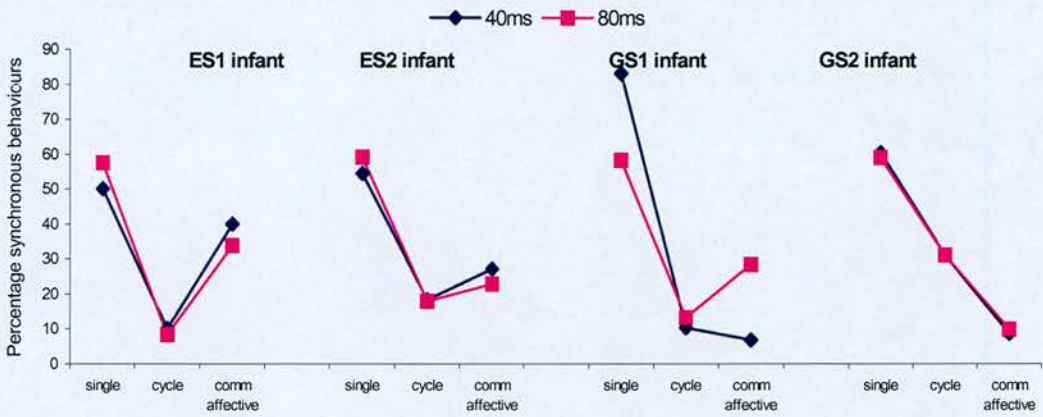
In this section, the kinds of behaviours mothers and infants display in order to synchronise with the musical beat are explored. In particular the focus is on: a) kind of synchronous behaviours single, cyclical or communicative-affective; b) the most common cyclical behaviours produced; c) category of synchronous behaviours: head or body, limbs, i.e. hands or legs, in contact with the partner, or with a toy. In the following figures, behaviours in synchrony with the musical beat are expressed as a percentage of the total number of synchronous behaviours. In particular, the figures relative to kinds of behaviours, the most common cycles of and category of synchronous behaviours will be presented as a function of dyad and condition.

Figure 5.22 Percentage of mothers' kinds of behaviours in synchrony with beat as a function of mother, collapsed across conditions



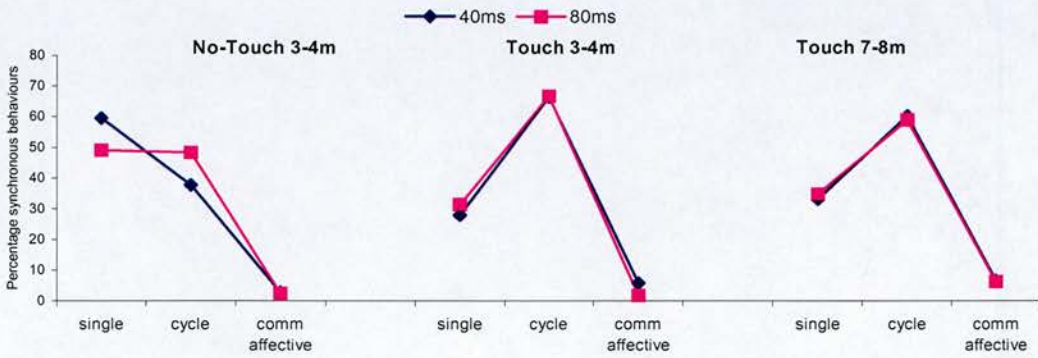
As Figure 5.22 shows, there is little variation in the mothers' kinds of synchronous behaviours in relation to latency. Apart from the ES1 mother, the others synchronise with the musical beat mostly through cyclical behaviours. However, at 40ms latency, the GS1 mother uses a similar percentage of single gestures and cyclical behaviours to synchronise with the beat, but at 80ms latency she favours cyclical actions. On the other hand, all the mothers very rarely match communicative-affective behaviours with the musical beat.

Figure 5.23 Percentage of infants' kinds of behaviours in synchrony with the beat as a function of infant, collapsed across conditions



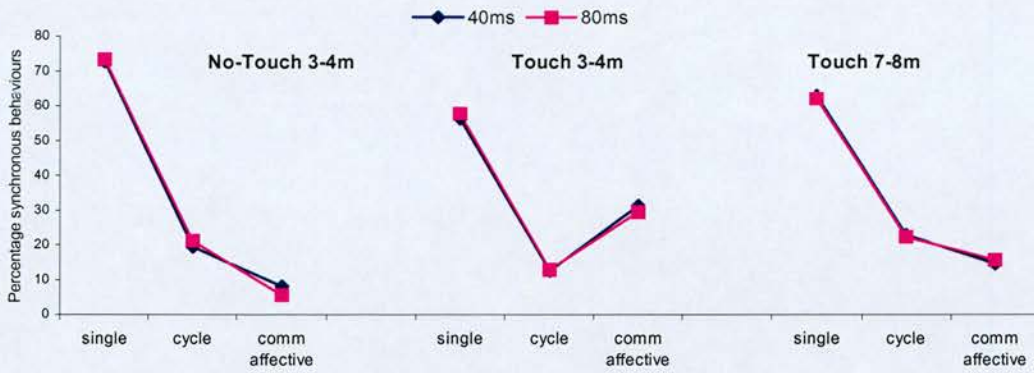
In Figure 5.23, it appears that similarly to their mothers, infants show little differences in relation to latency. However, unlike their mothers, infants synchronise more often with the musical beat through their single gestures and less often with their cyclical actions. All infants produce emotional behaviours in synchrony with the beat, and in particular the ES1 infant uses communicative-affective behaviours more frequently than the other infants. By contrast, the GS2 infant produces more cyclical behaviours in synchrony with the beat compared to the other infants.

Figure 5.24 Percentage of mothers' kinds of behaviours in synchrony with beat, as a function of context and age



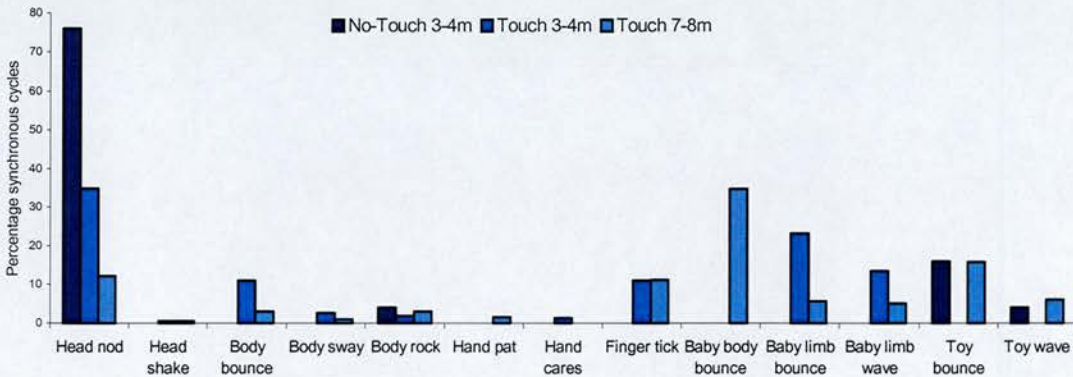
As Figure 5.24 shows, mothers do not show great difference in kinds of synchronous behaviours in relation to latency. With respect to age, mothers synchronise most often with the beat through their cyclical activity. On the other hand, during the no-touch context mothers perform the highest amount of single behaviours in synchrony with the beat at 40ms latency, compared to the touch context.

Figure 5.25 Percentage of infants' kinds of behaviours in synchrony with beat, as a function of context and age



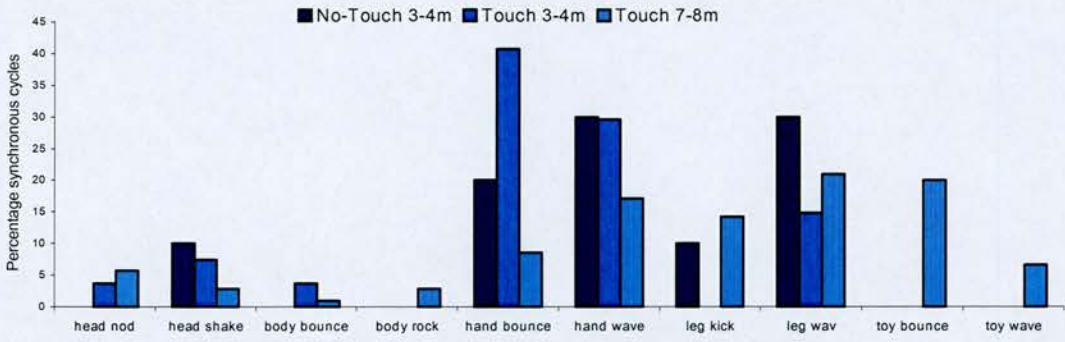
In Figure 5.25 once again, it appears that latency does not affect the infants' kinds of synchronous behaviours across conditions. Overall infants synchronise with the beat mostly through single gestures. Interestingly in both touch contexts they display less synchronous single gestures compared to the no-touch context. Infants also produce several communicative-affective behaviours in synchrony with the beat, in particular during the touch context at 3-4 months.

Figure 5.26 Percentage of mothers' cyclical patterns in synchrony with the beat, as a function of context and age



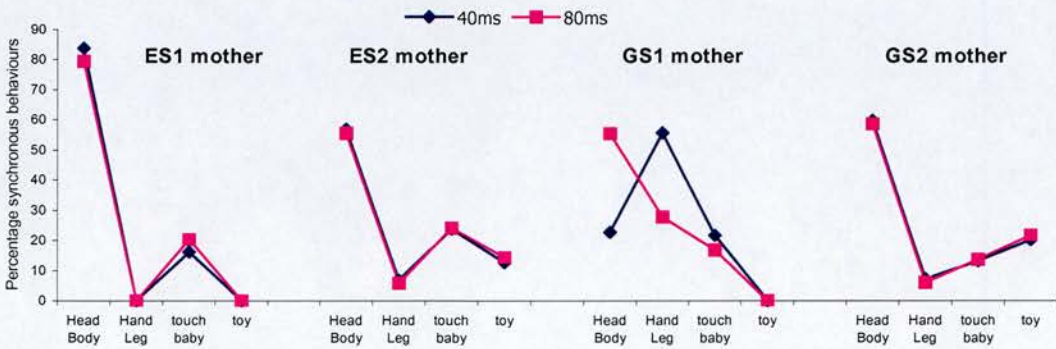
From Figure 5.26 it emerges that across all the conditions mothers nod their head in synchrony with the beat. Moreover, head nodding is the main synchronous cyclical behaviour during the no-touch context, with mothers only occasionally producing toy cycles. When the mothers are allowed to touch their infants, they produce a great variety of cycles in synchrony with the beat especially at 7-8 months. However, in the touch context at 3-4 months mothers produce quite a lot of head nodding, some body bouncing, and numerous cycles in contact with the infant, like finger tickling and moving the infant's limbs. But at 7-8 months mothers produce mostly cycles in direct contact with the infant's body.

Figure 5.27 Percentage of infants' cyclical patterns in synchrony with the beat, as a function of context and age



Infants display different synchronous cycles with the musical beat according to age and context, as shown in Figure 5.27. During the no-touch context at 3-4 months they synchronise with the beat mostly with their limbs, especially waving, and some head shaking. On the other hand, in the touch context at 3-4 months, infants produce a higher amount of hand cycles, especially hand bouncing, but fewer leg cycles compared to the no-touch context. However, when they are 7-8 months of age, not only do they increase the amount of leg cycles and head nodding compared to 3-4 months, but they also increase their variety of cyclical patterns, moving the toy in cycles and rocking the body.

Figure 5.28 Mothers' percentage of category of behaviours in synchrony with the beat, as a function of mother, collapsed across conditions



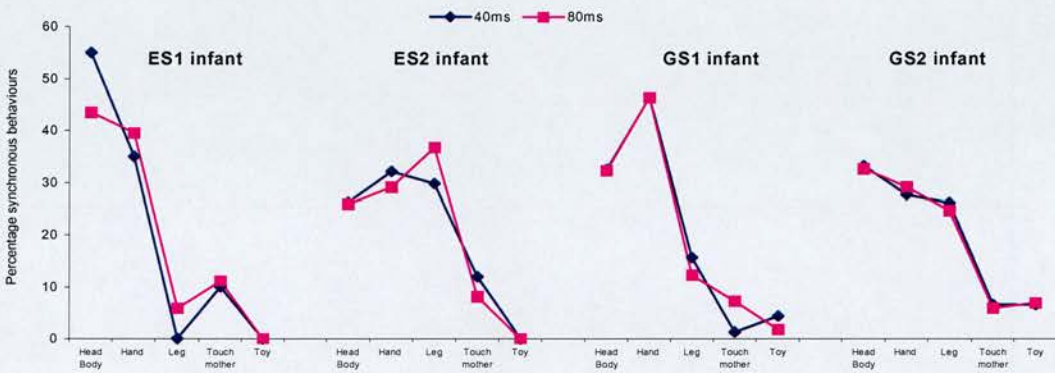
The categories of behaviours mothers perform in synchrony with the beat across conditions consist firstly in movements of head and body, and secondly in movements that include contact with their infants (see Figure 5.28). The pattern of behaviour is very similar for the ES and GS2 mothers, but the GS1 mother appears to synchronise mostly with her hand and leg at 40ms, and at 80ms latency she increases her head and body behaviours in synchrony with the beat, similarly to the other mothers. The ES2 and GS2 mothers often use a toy to synchronise with the beat.

Figure 5.29 Percentage of mothers' category of behaviours in synchrony with beat, as a function of context and age



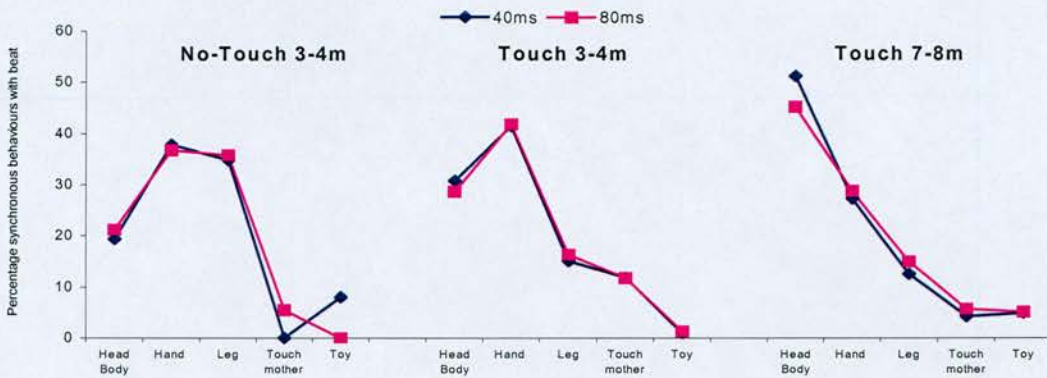
As Figure 5.29 shows, across conditions mothers synchronise with the musical beat mostly through their head and body behaviours. However, in the no-touch context and at 7-8 months mothers also move a toy in synchrony with the beat.

Figure 5.30 Percentage of infants' category of behaviours in synchrony with beat, as a function of infant, collapsed across conditions



Although infants often synchronise with the beat through their head and body actions, as Figure 5.30 shows, it is interesting to observe that they often also use their hand and leg behaviours to synchronise with the beat. In particular the GS1 and ES1 infants very often use their hands in synchrony with the beat. The ES2 and GS2 infants, by contrast, seem to move frequently hand and leg in synchrony with the beat. All infants occasionally touch their mothers in synchrony with the musical beat, whereas only the GS infants move the toy in synchrony with the beat, and even then very little.

Figure 5.31 Percentage of infants' category of behaviours in synchrony with beat, as a function of context and age



In Figure 5.31 it emerges that infants somewhat show slightly different patterns of synchronisation with the musical beat across conditions. For instance, at 3-4 months during the no-touch context infants perform mostly hand and leg behaviours in synchrony with the beat, although they also produce some movements with the toy at 40ms. On the other hand, during the touch context infants not only display numerous hand gestures in synchrony with the beat compared to the no-touch context, but they also produce several behaviours in contact with their mothers. However, this changes when infants are 7-8 months of age. In fact, at this later age infants synchronise more often with their head and body, and much less with their hand, leg, or behaviours in contact with the mothers.

5.2.6 Discussion and conclusions regarding mothers' and infants' synchrony with the beat

Both partners of the dyad perform behaviours in synchrony with the musical beat at 40ms and 80ms latencies, as predicted. In fact, they produce almost a third of their behaviours in synchrony with the musical beat across conditions. Moreover, both partners synchronise with the beat mostly at 40ms latency. This suggests that mothers and infants organise their behaviours so as to match closely the beat rather than around it. Chi square analyses revealed that only the mothers synchronise significantly with the beat, whereas the infants either do not synchronise significantly with the beat or the significant effect goes in the opposite direction. In fact, often the infants, and occasionally the mothers, produce significantly less synchronous behaviours with the beat than would be expected. Although Chi square analysis does not explain how the behaviours are distributed in the non-synchronous window there are a few reasons why this may happen. For instance, the infants might regularly miss the beat, or systemically produce behaviours in the gap between beats. In this case, they organise their behaviours in syncopation with the beat. With respect to

conditions it emerges that during the no-touch context at both latencies, the Chi square analysis presented in section 5.2.2, showed that mothers and infants do not synchronise significantly with the beat, although at the larger temporal window infants show a significant effect in the opposite direction. Consistent with this finding is the fact that in the no-touch context mothers display little accuracy with the beat compared to the touch context. Although at 40ms latency infants display similar levels of accuracy in the no-touch and touch contexts, at 80ms latency infants are less precise in the no-touch context. A closer look at the synchronisation with the beat in the no-touch context shows that both partners synchronise more frequently 40ms after the beat, with the mothers also doing so at 80ms after the beat. This suggests that in the absence of physical contact, mothers are more focused on their infants than on the music, thus synchronising less precisely on the beat.

When the 3-4 months touch context is considered, Chi square analyses show that mothers produce significantly less behaviours than expected with the larger temporal window (i.e., 80ms) but no significant effect with the smaller temporal window. On the other hand, the infants display a significant effect in the opposite direction than would be expected at both temporal windows. Interestingly in this context both mothers and infants display a better accuracy with the musical beat compared to the no-touch context. In particular, infants match often exactly on the beat whereas mothers synchronise before, on and after the beat. Moreover infants were found to be highly engaged with the musical interaction compared to both the no-touch context and the older age (see Chapter 4, Figure 4.15). Although all these behaviours would suggest that in this condition music could be well integrated into the interaction, infants do not synchronise significantly with the beat. In fact, infants move significantly more often off the beat which might suggest that they syncopate with the beat. In the touch context at 7-8 months, at both latencies, Chi square analysis shows that mothers do not synchronise significantly with the beat, whereas infants produce significantly less behaviours in synchrony with the beat than expected. Overall both partners' show less precision when matching the beat compared to 3-4 months. In particular, mothers and infants synchronise more frequently after the beat, although the infants also appear to match often 80ms before the beat. Familiarisation with the songs and a more advanced co-ordination of their behaviours may well allow the older infants to synchronise accurately with the beat. However, despite the prediction that infants would synchronise more precisely at 7-8 months, they turned out to be more accurate at 3-4 months. Thus, despite the fact that at 7-8 months infants are potentially more familiar with the songs and better co-ordinated, they seem to be less focused on the musical event. In fact, in Chapter 4 (Figure 4.15) it emerged

that at 7-8 months infants displayed fewer instances of high engagement than at 3-4 months. Therefore, in the absence of physical contact or when the infants are older, the partners of the dyad appear to synchronise with the beat less precisely, suggesting that in these conditions the partners are less concentrated on the music.

When the musical tempo of the songs is considered in relation to the partners' synchronous behaviours with the beat, some differences emerge. First of all, mothers and infants appear to produce more synchronous behaviours with the beat during faster tempos compared to slower ones. In fact, both partners match the beat more frequently with *presto* tempo songs compared to *largo*, the latter being when they synchronise the least. Although across musical tempos they do not show any overall difference of accuracy, they show some interesting patterns in relation to the region of the beat on which they synchronise more often. In fact, it appears that during the *largo*, *andante* and *allegro* tempos, both partners of the dyad synchronise more often after the beat, whereas during the *presto* tempo they match frequently 80ms before the beat. Chi square analyses showed that both partners of the dyad do not synchronise significantly with the beat for *presto* tempo songs. Also during *largo* tempo mothers display a non-significant effect of synchrony with the beat at both latencies, whereas infants produce significantly less synchronous behaviours with the beat than expected. This might be explained along the lines of Fraisse (1964) who suggested that when there is a long interval between onset stimuli, the perception of a gap between stimuli is dominant and it becomes more difficult for the listener to join together the onset of the stimuli. Therefore, according to Fraisse, intervals at medium tempo should be more easily perceived because they are more natural to the listener. On this point, Pouthas (1996) suggested that adults can tap in precise synchrony with an inter-stimulus interval between 400 and 800ms. In fact, Pouthas claims that with this temporal interval, adults display the beat of their synchronisation because it is closer to the spontaneous tempo as well as the preferred tempo put forward by Fraisse (1964, 1982). In fact, mothers match significantly the beat only during *moderato*, at 80ms temporal window, and at 40ms latency *allegro* musical tempo. Thus it seems that, especially for the mothers, medium to fast tempos are more suited for synchronisation with the beat. By contrast, infants tend to produce significantly less synchronous behaviours with the beat than expected at any tempo except *presto*. Thus, during slow and medium to fast tempos infants might regularly miss the beat, or organise their behaviours between beats or completely away from the beats. However, my findings suggest that infants, and partially the mothers, fail to synchronise with the musical beat not only with slow songs, i.e., at the *largo* tempo, but also with medium to fast tempos songs,

i.e., *moderato*, *andante* and *allegro*. So why do both partners show difficulties in synchronising with the musical beat of songs at this pace? Jones (1982) and Jones and Boltz (1989) suggested that infants are more sensitive to faster tempos than slower ones because of their biological attending to internal tempos which correspond to faster tempos. On the other hand, songs at medium to fast musical tempos might set the pace of the interaction between mothers and infants. In this way the song is not an event external to the dyad but becomes itself the interface of the mother-infant interaction.

When one considers the partners' behaviours that are synchronous with the beat across the phrases of the song, it emerges that although there are variations, both mothers and infants display some interesting regularities as a function of condition and musical tempo. This is in contrast with the prediction that mothers would distribute evenly their synchronous behaviours with the beat whereas infants would show variation. The analysis of variance was employed to determine the effect of phrase and number of synchronous behaviours with the beat that the mothers produce as a function of condition. It showed that at both latencies there is no main effect of phrase but there is a significant effect of condition (at 80ms latency only). The main significant effect of condition suggests that mothers modify their number of synchronous behaviours with the beat as a function of condition. In particular, from Figure 5.16, it seems that there is a greater effect of context compared to age. In fact, in the no-touch context mothers synchronise less often with the beat compared to the touch context. A significant interaction emerged between phrase and condition, suggesting that mothers synchronise with the beat more frequently in certain phrases than others as a function of condition. In fact, they seem to synchronise frequently with the beat in the 2nd phrase in both touch contexts at 3-4 months and 7-8 months, and the 1st phrase in the no-touch context. Thus, again, physical contact may affect more than age the way in which mothers organise their synchronous behaviours across the phrases of the song. Interestingly, when the mothers' level of activity in the phrases of the song is considered (see Chapter 4, section 4.3.1), it emerged that mothers produce significantly more behaviours in the 1st phrase of the song compared to the others, irrespective of condition. Therefore, it seems that only in the absence of physical contact is there a relation between the mothers' level of activity and their synchronous behaviours with the beat across the phrases of the songs. On the other hand, when consideration is given to how infants synchronise with the beat across the phrases of the song as a function of condition, the analysis of variance showed that at both latencies there is no main effect of phrase or condition. Therefore infants' number of synchronous behaviours with the beat varies across the phrases of the song as a function of condition.

Moreover, they do not vary significantly the number of synchronous behaviours with the beat as a function of context or age. However, the analysis of variance shows a significant interaction between phrase, pair and type of beat which suggests that infants vary the number of synchronous behaviours with the beat according to certain beats and phrases. The significant interaction between pair, phrase and condition, although not easy to interpret, suggests that infants modify their synchronisation with the beat across the phrases of the song as a function of certain beats, context and age. In fact, as Figure 5.16 illustrates, infants synchronise more often on the beat in the 1st phrase at both 3-4 months and 7-8 months, whereas in the no-touch context they match more often the beat in the 4th phrase of the song. This means that physical contact affects how both infants and mothers synchronise their behaviours with the beat across the phrases of the song. Interestingly, when the infants' level of activity is considered it emerges that infants produce a significantly higher level of activity in the 1st phrase of the song irrespective of context or age (see Chapter 4, section 4.3.1). Therefore, although there may be some relation between the infants' level of activity and the number of behaviours in synchrony with the beat, this relation becomes more relevant when physical contact is taken into account.

With respect to the musical tempo of the songs and the partners' amount of synchronous behaviours across the phrases of the song, it emerged that there is no main significant effect of phrase but there is a main significant effect of musical tempo, at both latencies. This means that mothers and infants vary significantly the number of behaviours in synchrony with the beat across the phrases of the song as a function of musical tempo. Data from Figures 5.17 and 5.18 show that in fact both partners produce a very small number of synchronous behaviours with the beat during the *largo* tempo. By contrast, during the *presto* tempo they produce a higher number of synchronous behaviours with the beat. Moreover, there is again a significant interaction between phrases and musical tempos at both latencies (although at 40ms latency mothers show only a trend). This suggests that mothers and infants modify the amount of their synchronous behaviours with the beat in the phrases of the song as a function of the tempo of the songs. For instance, with the *allegro* tempo, the mothers appear to synchronise frequently with the beat in the 2nd phrase of the song, whereas during the *andante* tempo it is in the 1st phrase, and with the *largo* tempo is difficult to tell. Again when the mothers' level of activity across the phrases of the song is considered, as discussed in Chapter 4, section 4.3.1, it emerges that mothers show a significant level of activity in the 1st phrase of the song during the *largo*, *andante* and *allegro* tempos. Therefore, it seems that only during the *andante* tempo songs is there a relation between the mothers' level of

activity and their amount of synchronous behaviours with the beat. On the other hand, infants show even more variation than their mothers in their number of synchronous behaviours with the beat across the phrases of the song as a function of tempo. For instance, during the *andante* tempo they synchronise more often with the beat in the 3rd phrase of the song and with the *largo* tempo in the 1st phrase, whereas with the *allegro* tempo they produce the least of synchronous behaviours in the 2nd phrase of the song. When their level of activity in the phrases of the song is considered, it emerges that infants show a significant effect in the 1st phrase across musical tempos (see Chapter 4, section 4.3.1). Thus it seems that there is little relation between the mothers' and the infants' level of activity and their synchronous behaviours across the phrases of the song as a function of musical tempo. Although both partners display considerable differences in the level of synchronous behaviours with the beat in the phrases of the song, some tendencies emerged, especially in relation to condition and musical tempo. It is possible that with a larger group of participants these tendencies would reach significance. Finally, because the partners' variations in the phrases of the song seem to be clearer at 80m than at 40ms latency, it could be that with respect to the phrase of the song, there is less of a need for the partners to cluster their behaviours tightly because the phrase lasts for few seconds.

When the partners' synchronisation with the musical beat is considered in relation to beat position and the metrical structure of the song, an interesting picture emerges. In particular, the same analysis of variance used in Chapter 3, section 3.2.1, to examine the duration of the beat when mothers sing to their infants was applied here to explore the effect of beat position in relation to the number of synchronous behaviours of the partners with the beat. First of all, the mothers show a significant interaction between pair and type of beat suggesting that they synchronise significantly more often with certain beats than others according to the pair. In general, they seem to synchronise more often on upbeats than downbeats. Thus again the mothers appear to highlight the main beats of the song, i.e., the downbeats, emphasising and anticipating for their infants through their singing and behaviours where the upbeats will appear. In particular, pairwise comparisons showed that they synchronise significantly more often with the 4th and 8th beats compared to the others. This is interesting because those beats are the same ones that the mothers extended while singing (see Chapter 3, section 3.2.1). Therefore mothers make sure that they convey to their infants the same segmentation of the song while singing and moving their body. In fact, through their synchronous behaviours with the beat the mothers mark the boundary between phrases, i.e., synchrony on the 8th beat, and the midpoint of the phrase, i.e., synchrony on the 4th beat. Furthermore, some

significant interactions were found, especially at 80ms latency. For instance, previously I mentioned the significant interaction between phrase and condition. Another interaction that approaches significance at 80ms latency occurred between pair and condition, suggesting that mothers modify their synchronous participation on the beats in relation to context and age. In fact, from Figure 5.21 it emerges that in the touch context at 3-4 months, mothers synchronise very often on the 1st, 2nd and 4th pair, i.e., on the 1st, 2nd, 4th and 8th beats. By contrast, at 7-8 months mothers synchronise mostly on the 2nd and 4th pairs which involve the 4th and 8th beats especially. The same pattern emerges in the no-touch context. Thus it seems that in the absence of or with little physical contact, mothers emphasise with their behaviours exactly the same beats that they extend while singing. On the other hand, when there is physical contact and when the music is perhaps more integrated into the interaction, mothers not only stress the middle and the end of the phrase, they also emphasise the beginning of the phrase. Therefore, mothers seem to propose another level of segmentation which might help infants to process the musical event better. In sum, through their singing and synchronous behaviours, mothers convey via different modalities the temporal structure of the song and of the dyadic interaction, using temporally synchronised auditory, visual, vestibular, kinaesthetic and tactile stimuli.

When the infants' synchronisation with the musical beat is considered, it appears that they understand the temporal structure of the song emphasised by their mothers through their singing and synchronous behaviours, because they produce significantly more behaviours in synchrony with certain beats rather than others. At 40ms latency infants show a significant effect of pair which means that the infants synchronise significantly more often with the beat for certain pairs rather than others. From the data in Table 5.8 it appears that infants produce a higher number of synchronous behaviours with the beats in the 2nd pair, suggesting that they tend to match the beat especially in the middle of the phrase. Interestingly at 80ms latency, infants also display some significant interactions. The significant interaction between phrase, pair and condition has already been mentioned, and it suggests that infants match more often with certain beats across the phrases of the song as a function of context and age. Another significant interaction already mentioned occurs between phrase, pair and type of beat and indicates that infants produce more synchronous behaviours on certain beats according to the phrase of the song. Interestingly, similarly to their mothers, infants show a significant interaction between pair and type of beat, i.e., downbeat/upbeat, which indicates that infants synchronise with the beats according to their position in the phrase. Interestingly infants synchronise more frequently on the upbeats at 40ms latency, and on the downbeats at

80ms latency. Pairwise comparisons showed that infants synchronise significantly more often on the 1st 4th 5th and 8th beats compared to the others. This is relevant not only because infants synchronise with those beats stressed more by their mothers, i.e., 4th and 8th beats, but also because they synchronise significantly on the 1st and 5th beats which represent the main downbeats. This suggests indeed that infants understand their mothers' emphasis on the middle and end parts of the phrases and accordingly match with those beats especially. Moreover, infants seem to perceive the 'gap effect' on the downbeats created by the mothers, matching more frequently on those beats at 80ms latency, thus demonstrating that they are sensitive to the temporal structure of the song provided by the mother.

Regarding the kinds of behaviours the partners produce more frequently in synchrony with the musical beat, as hypothesised mothers perform more cyclical patterns whereas infants produce more single gestures. However, against my prediction, there is an effect of context: during the no-touch context mothers synchronise with the beat mostly with single gestures, whereas in the touch context they are more likely to perform cyclical synchronous behaviours. It is probable that because of the lack of physical contact, mothers have more difficulty in organising their cyclical actions in synchrony with the beat. A closer look at the mothers' synchronous cycles reveals that mothers perform mostly vertically-oriented cycles in synchrony with the beat. Moreover, mothers change style of cyclical patterns according to context and age. Thus, during the no-touch context at 3-4 months mothers perform mostly visual cycles, i.e., head nodding and a few toy cycles. In the touch context at 3-4 months they increase the modalities of cyclical synchronous activity: visual, i.e., head nodding, vestibular, i.e., body bouncing, tactile, i.e., finger tickling, and kinaesthetic, i.e., moving infant's limbs. At 7-8 months, mothers focus their synchronous cyclical activity on the tactile, i.e., finger tickling, and kinaesthetic, i.e., moving the infant's body and limbs, and the visual stimuli shifts from the mother, i.e., head nodding, to the toy. Thus, they appear to match the beat in relation to tactile and kinaesthetic stimulation in contact with the infants which is more peripheral, i.e., involves touching and moving their limbs when they are younger. By contrast, with age mothers synchronise with the beat moving the infants' whole body. When the categories of mothers' synchronous behaviours with the beat are considered, it emerges that they match the beat mostly through their head and body and secondly with behaviours in contact with their infants. Thus, although in general mothers seem concerned about over-stimulating their infants, they appear to be less so when this involves conveying temporal structure. On the other hand, infants perform mostly single gestures in synchrony with the beat and, aside from the GS2 infant, the others often produce

communicative-affective behaviours in synchrony with the beat. Also across conditions infants synchronise mostly with the beat through their single gestures. However, as predicted, at 7-8 months of age infants increase slightly their cyclical behaviours in synchrony with the beat compared to the 3-4 months context although they still synchronise mostly through single gestures. Thus, as they grow older, infants become not only stronger but also more co-ordinated and organise their actions in cycles more often with the beat. Also in the no-touch context at 3-4 months infants perform a high amount of cyclical behaviours compared to touch context. Although the lack of physical contact seems to play a part in the production of cyclical behaviours in synchrony with the beat, a more detailed account of the infants' cycles reveals that infants also change the style of synchronous cyclical patterns in relation to age and context. In the no-touch context at 3-4 months they synchronise mostly with hand and leg waving cycles. In the touch context at 3-4 months they increase the amount of hand bouncing, also produce some head and body cycles, but only very few legs cycles. At 7-8 months, there is a change in the infants' cyclical activity in synchrony with the beat. In fact, at this time they produce synchronous cycles with their head, body, hands, legs and toy. My findings run counter to Moog's (1976) hypothesis that infants synchronise with behaviours from different parts of the body when they are younger and towards the end of the first year focus on few parts. In fact, I found that infants synchronise with the beat through few limbs cycles when they are 3-4 months old, but when they are 7-8 months they display greater variety and use different parts of the body plus the toy. When the categories of infants' synchronous behaviours are considered, they appear to synchronise with the musical beat according to context and age. In fact, in the no-touch context at 3-4 months infants synchronise with the beat mostly through their hand and leg behaviours. On the other hand, in the touch context at 3-4 months they match the beat through hand, head and body behaviours as well as actions in contact with their mothers. Finally, at 7-8 months, they synchronise more often with their head and body behaviours but less often use limbs and contact with their mothers, compared to the 3-4 months context. Therefore, when older, infants seem to display a pattern more similar to their mothers, matching the beat mostly through their head and body. Finally, it is interesting to note that infants' kinds and categories of synchronous behaviours with the beat appear to maintain the same overall pattern in both temporal windows suggesting that they are robust patterns.

In sum, mothers were predicted to synchronise with the beat in order to convey a temporally organised form of participation to their infants. In fact, mothers were found to synchronise often with the musical beat. Their precision with the beat was expected to give rise to an

anticipation of 20 to 50ms before the beat as suggested by Pouthas (1996). By contrast, my findings show that mothers tend to synchronise around 40ms after the beat. This might be due to the fact that in my study, mothers were engaged in an interaction when they synchronised with the beat, whereas Pouthas' participants were not. Mothers were expected to show similar amounts of synchronous behaviours with the beat as well as similar accuracy across conditions. It was found that indeed mothers display similar amounts of behaviours in synchrony with the beat irrespective of context and age. However, they seem less accurate in the no-touch context compared to the touch one. I expected that mothers would synchronise similarly with the beat across all conditions. In fact, the mothers were found to produce similar amounts of synchronous behaviours with the beat. Chi square analyses showed that mothers do not synchronise significantly with the beat in any of the conditions. Although no prediction was made regarding the mothers' synchronisation with the musical beat, it emerged that mothers produce more synchronous behaviours with the beat as a function of tempo of the song: the faster the song the higher the amount of behaviours in synchrony with the beat. Moreover, Chi square analyses showed that mothers synchronise significantly with the beat of moderate to fast tempo songs rather than slower ones. I hypothesised that mothers would stress the metrical structure with their behaviours in synchrony with the beat similarly to the way in which they extended the duration of the beat while singing. In fact, the mothers synchronise significantly more often on the 8th and 4th beats compared to the others. Mothers were expected to synchronise with the beat similarly across the phrases of the song. Although the analysis of variance did not show a main significant effect of phrase as a function of tempo or condition, significant interactions emerged between phrase and musical tempo as well as between phrase and condition. Thus, mothers significantly vary the amount of synchronous behaviours with the beat across the phrases of the song as a function of condition and musical tempo. Mothers were predicted to match the beat mostly through their cyclical behaviours and indeed they did so. Finally, mothers were expected to increase the amount of synchronous behaviours in contact with their infants at 7-8 months compared to 3-4 months. Although they did increase the amount of cyclical synchronous behaviours in contact with their infants, overall at 7-8 months they did not increase the amount of total synchronous behaviours in contact with the infants compared to 3-4 months.

With respect to infants, they were predicted to synchronise their behaviours with the beat, and the results show that they do. Although I hypothesised that infants would produce a higher and more precise amount of synchronous behaviours with the beat at 7-8 months compared to 3-4 months, a different picture emerged. In fact, infants do not show different

amounts of synchronous behaviours with the beat in relation to age; rather they show different levels of precision. In contrast with my prediction, they appear less accurate at 7-8 months than at 3-4 months. I expected that there would not be an effect of context when infants synchronise with the beat. In fact, infants produce more synchronous behaviours with the beat in the no-touch context compared to the touch one, but they do not show a significant effect of synchrony with the beat in neither of the contexts. Overall, infants' accuracy with the beat is similar across contexts, but it is in the touch context that they tend to synchronise precisely on the beat. Although no prediction was made regarding the infants' synchronisation with the beat and the musical tempo, it emerged that although infants tend to produce more synchronous behaviours with faster tempo songs than slower ones, Chi square analyses showed that they do not synchronise significantly with the beat at any particular tempo. I hypothesised that infants would show an understanding of the temporal structure of the song at 7-8 months synchronising on the main beats, i.e., downbeats. The analysis of variance showed that overall infants are sensitive to the temporal structure of the song, synchronising more often with the beats stressed by their mothers. In fact, they tended to synchronise significantly with the 1st 4th 5th and 8th beats compared to the others. Therefore the infants are not only sensitive to the beats emphasised by their singing mothers, i.e., 4th and 8th beats, but also to the temporal structure emphasised by their mothers matching significantly more often the 1st and 5th beats which represent the main downbeats. Interestingly this occurs independently of condition, thus refuting my prediction that infants would synchronise with the downbeats at 7-8 months but not at 3-4 months. With respect to the infants' synchronisation with the beat in the phrases of the song, they were expected to show more variation than their mothers. Although infants display variation, they also show a significant interaction between phrase, pair and condition. Moreover, a relation between the infants' level of activity and their synchronous behaviours in the phrases of the song was predicted. The data showed some relation between the infants' level of activity and the number of synchronous behaviours with the beat across the phrases as a function of condition and musical tempo, but the relation is quite weak. Infants were predicted to show no difference in the kind of synchronous behaviours with the beat in relation to context. In fact, they synchronise mostly through single gestures in both contexts. I expected that infants would increase their amount of cyclical behaviours in synchrony with the beat at 7-8 months compared to 3-4 months. Although they show a slight increase of cyclical synchronous behaviours, they still synchronise more frequently with single gestures. With respect to category of synchronous behaviours, infants were expected to use different parts of their body at 3-4 months irrespective of context. I found that infants match more

frequently the beats with their hand and leg behaviours in the no-touch context, and mostly with their hand in the touch context, thus partially supporting my prediction. However, contrary to the prediction that infants would match the beat with their limbs mostly at 7-8 months, it emerged that infants synchronise more often with their head and body when older.

5.3 Do mother and infant display synchronisation with each other during interactions with songs?

Synchronisation is not only important for its relation with internal organisation and external co-ordination with an auditory stimulus. In an interaction, synchronisation also involves the ability of the partners to co-ordinate with each other's activity. Condon (1979) emphasised that in an interaction, the participants organise their verbal and non-verbal behaviours temporally, as in a dance. He further argued that “..such integration (or organisation) is manifested in the synchronised timing or changing together of the aspects of behaviour with each other, including both speech and body motion” (Condon, 1979, in Bullowa, p.131). According to Condon, when the listener moves in synchrony with the phrases and words of the speaker there is ‘interactional synchrony’. He termed ‘responsive entrainment’ the internal process that allows a person to synchronise. However, interactional synchrony does not only occur between adults. In fact, Condon and Sander (1974) demonstrated that newborns (1 to 4 days old and even only 20 minutes old) are able to entrain within 50ms with either the live human voice or a tape recorder. Condon was not the only researcher to observe synchronous behaviours between the partners of a dyad. In fact, several researchers suggested that harmonious interactions between partners of the dyad are synchronous (Beebe et al., 1982; Brazelton et al. 1974; Papousek, 1996; Tronick, Als, Adamson, Wise & Brazelton, 1977). An important aspect of synchronous interaction is that it is indicative of a healthy and qualitatively positive interaction. For instance, when mothers are depressed, they pay less attention to their infants' state and are less likely to match with their infants' behaviours (Field, 1984; Field et al. 1985; Cohn et al., 1986). Although mother-infant synchronisation is considered to be important for interaction, this phenomenon has not hitherto been explored during musical interaction.

I address the following questions: Do mother and infant synchronise with each other's behaviours during musical interaction with songs? If so, how accurate are they in their synchronisation? How many behaviours will the mother synchronise with the infant and vice versa? Does physical contact affect their ability to synchronise? Does musical tempo

affect their synchronisation with each other? Do they relate their synchronous behaviours to the phrasing structure of the songs? Which kind and category of synchronous behaviours will the partners display the most?

Mothers and infants were predicted to synchronise their behaviours with each other during interactions with songs. In particular I predict that amount and accuracy of mother and infant synchronous behaviours will be related to physical contact and age of the infant. In fact, it is anticipated that during the no-touch context at 3-4-months of age, infants will find it more difficult to synchronise with their mothers compared to the touch context. At 7-8 months, infants are expected to show more synchronous actions compared to 3-4 months. I predict that the percentage of the mother's behaviours that are synchronous with the infant's behaviours will be higher than the percentage of the infant's behaviours that are synchronous with the mother's behaviours. No specific prediction is made regarding the effect of musical tempo on the synchronisation between the partners of the dyad. In relation to the phrasing structure of the song, I do not have a specific prediction about the number of the mothers' and infants' synchronous behaviours and the phrases of the songs. On the basis that the mothers will avoid over-stimulation of their infants in order to maintain a homeostatic state, they are predicted to produce synchronous actions of their body with the 3-4 month-old infant, whereas at 7-8months I expect them to use more synchronous actions in contact with the infant's body. I also anticipate that mothers will mainly use cyclical actions in all conditions. According to Moog's theory (1976), infants are predicted to synchronise with their mothers through every part of their body at 3-4 months, but that they will show more limb activity at 7-8 months of age. Infants are expected to synchronise more with cyclical actions at 7-8 months than at 3-4 months.

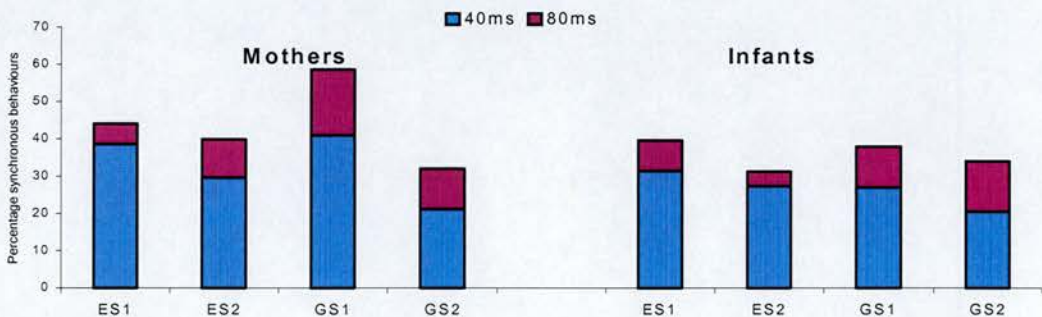
In order to test these hypotheses, the dataset of the interaction was used (see Chapter 3, section 3.2.1). This was collected by asking mothers to sing to their 3-4 month-olds in two contexts: no-touch and touch; as well as to sing to their 7-8 month-olds in a touch context only. In order to assess whether the mother's and infant's behaviours are synchronous with each other, their onset times are compared. When the partners' onset times behaviours occur within 40ms (i.e., 0ms to 40ms) and 80ms (i.e., 0ms to 80ms) temporal windows, they are considered in synchrony. Then the amount of synchronous behaviours that mothers and infants perform with each other is measured in relation to their overall participation in the interaction, with the distance between onset events also being analysed. Finally, the kind and

category of synchronous behaviours that mothers and infants produce with each other is examined.

5.3.1 Analysis of the mothers’ and infants’ behaviours in synchrony with each other in interaction with songs

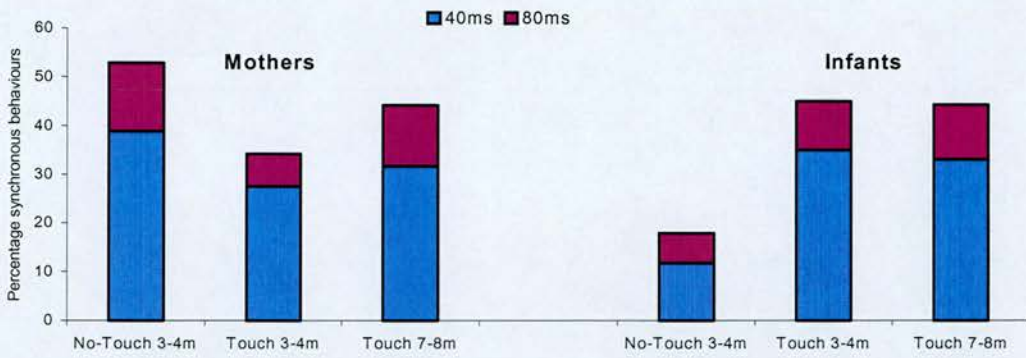
In this section the mothers’ and infants’ synchronisation with each other when the onset time of their behaviours occurs within 40ms and 80ms temporal windows are explored. A detailed explanation of the procedure applied to measure the mothers’ and infants’ synchronisation with each other was presented in Chapter 2, section 2.3.2.3. In particular in the current section, the focus is on: 1) the overall amount of synchronous behaviours mothers and infants perform in synchrony with the partner, expressed as a percentage of the overall amount of behaviours performed by the partner in the interaction; 2) the accuracy of synchronisation measured through mean distance between the onset times of the partners’ behaviours in synchrony with each other at 40ms as well as at 80ms latencies is expressed in milliseconds (thus the smaller the bar, i.e., closest to “0”, indicates more accuracy); 3) mothers’ and infants’ synchronisation with each other as a function of the phrases of the song; and, 4) kind and category of behaviours each partner produces in synchrony with the other.

Figure 5.32 Percentage of mothers’ and infants’ behaviours in synchrony with each other, as a function of dyad, collapsed across conditions



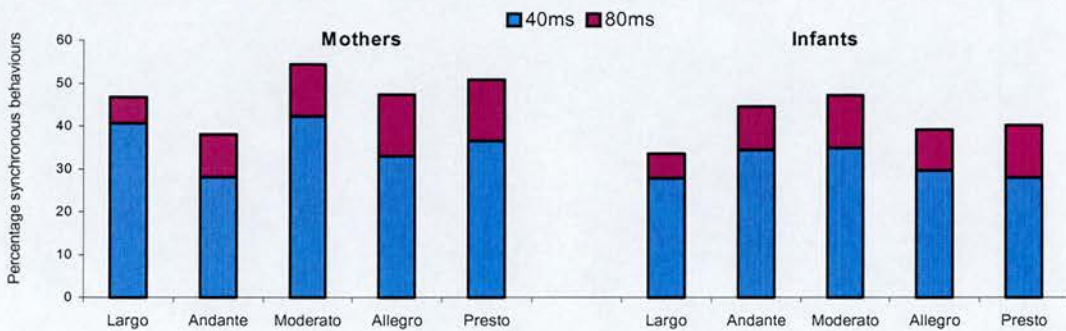
As Figure 5.32 shows, across conditions mothers seem to produce slightly more behaviours in synchrony with their infants’ actions compared to the amount of behaviours infants perform in order to match their mothers’. In particular, the GS1 and ES1 mothers perform a higher level of synchronous behaviours with their infants compared to the others.

Figure 5.33 Percentage of mothers' and infants' behaviours in synchrony with each other, as a function of context and age



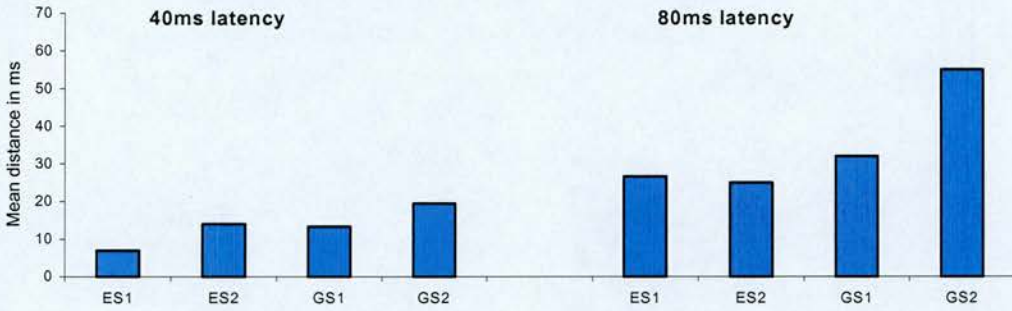
From Figure 5.33 it emerges that during the no-touch context at 3-4 months mothers produce a larger amount of behaviours in synchrony with their infants' behaviours compared to the touch context. On the other hand, in the no-touch context infants produce a small percentage of synchronous behaviours with their mothers' behaviours compared to the touch context. Finally, at 7-8 months mothers increase the amount of synchronous behaviours with their infants' behaviours compared to 3-4 months. By contrast, infants perform a similar amount of synchronous behaviours with their mothers' behaviours at both ages.

Figure 5.34 Percentage of mothers' and infants' behaviours in synchrony with each other, as a function of musical tempo



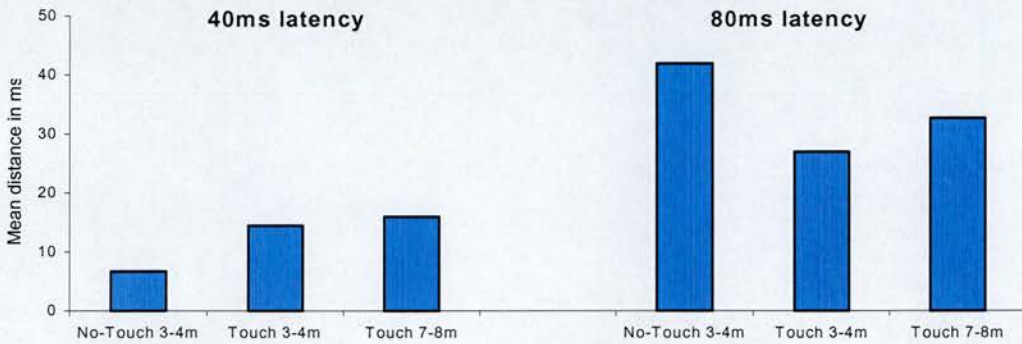
During the *andante* and *allegro* tempos, mothers produce a smaller percentage of behaviours in synchrony with their infants' behaviours compared to the other tempos. On the other hand, infants display a higher percentage of synchronous behaviours with their mothers' during *andante* and *moderato* tempos than the others.

Figure 5.35 Accuracy of mothers' and infants' synchronous behaviours with each other (mean distances between synchronous behaviours), as a function of dyad, collapsed across conditions



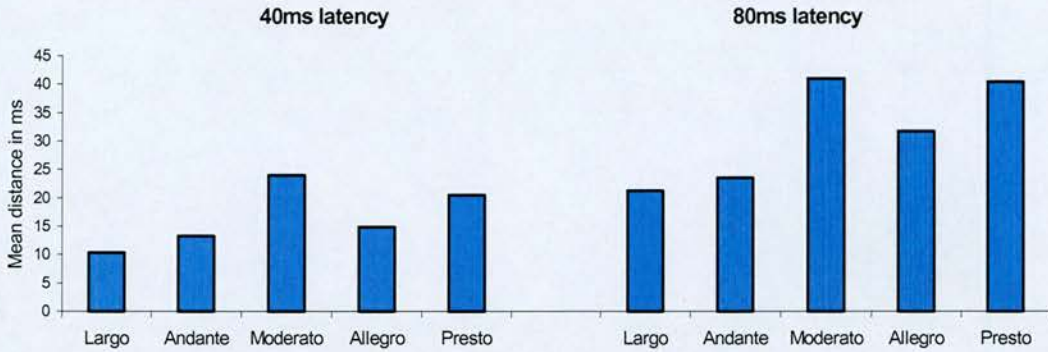
As figure 5.35 shows, when the data are collapsed across conditions the ES1 dyad is extremely accurate when partners synchronise with each other, especially at 40ms latency. At 80ms latency, both the ES dyads are more precise than the others. On the other hand, at both latencies the GS2 dyad appears particularly slow when matching each others' behaviours compared to the other dyads. This is especially true at 80ms latency.

Figure 5.36 Accuracy of mothers' and infants' synchronous behaviours with each other (mean distances between synchronous behaviours), as a function of context and age



When conditions are considered, it is interesting to observe the differences in synchronisation in relation to the temporal windows. In particular, at 40ms they are more in synchrony in the no-touch context at 3-4 months compared to the touch context. They show little difference in accuracy as a function of age. On the other hand, at 80ms latency the partners of the dyad synchronise with each other's behaviours much more accurately during the touch context at 3-4 months compared to the no-touch context. Moreover, at 7-8 months mothers and infants appear to be less precise in their synchronisation compared to 3-4 months.

Figure 5.37 Accuracy of mothers' and infants' synchronous behaviours with each other (mean distances between synchronous behaviours), as a function of musical tempo

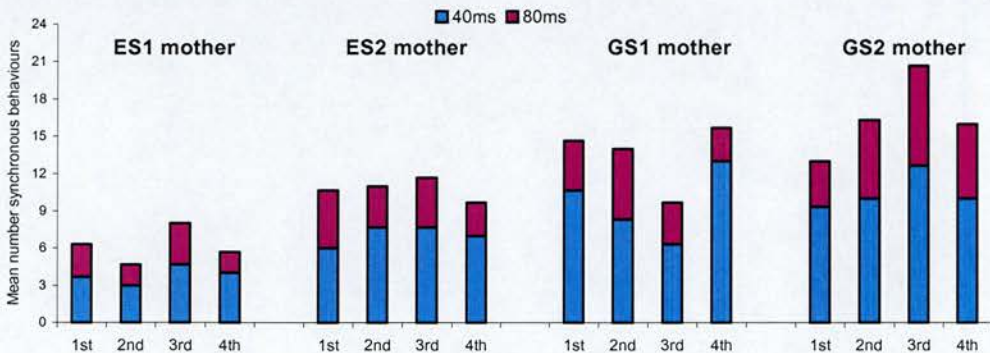


When musical tempo is considered the partners of the dyad seem to be more accurate in matching each other's behaviours during the *largo*, *andante* and *allegro* tempos compared to the other tempos. In fact, they show this pattern at both latencies.

5.3.2 Mothers' and infants' synchrony with each other as a function of each phrase of the song

This section explores how the mothers' and infants' behaviours that are in synchrony with the other partner's behaviours are distributed across the phrases of the songs. Figures 5.38, 5.39, 5.40, 5.41, 5.42 and 5.43 show the mean number of synchronous behaviours with the partner that mothers and infants perform as a function of dyad, condition and musical tempo. Again, synchronisation between mother's and infant's behaviours is defined as occurring when onset times are within the temporal windows of 40ms and 80ms.

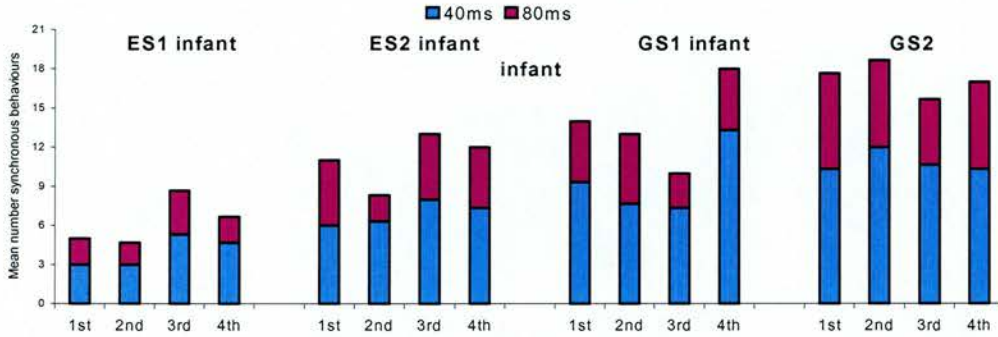
Figure 5.38 Mothers' mean number of behaviours in synchrony with their infants for each phrase, as a function of mother



The ES1 and GS2 mothers produce more behaviours in synchrony with their infants during the 3rd phrase of the song. By contrast, the GS1 mother performs the least of synchronous behaviours in the 3rd phrase; she matches more often with her infant during the 4th phrase of

the song. Finally the ES2 mother synchronises frequently with her infant in the 2nd and 3rd phrases at 40ms latency, and slightly more in the 3rd phrase at 80ms latency.

Figure 5.39 Infants' mean number of behaviours in synchrony with their mothers for each phrase, as a function of infant



Both the ES infants produce the majority of their behaviours in synchrony with their mothers during the 3rd phrase of the song. By contrast, the GS1 infant performs most of her actions in synchrony with her mother in the 4th phrase of the song. Finally, it is in the 2nd phrase of the song that the GS2 infant synchronises more often with his mother.

Taking Figure 5.38 and 5.39 together it appears that the ES1 and GS1 partners of the dyads synchronise more often in the same phrases respectively the 3rd and 4th phrases. The partners of the ES2 dyad synchronise more often in the 3rd phrase of the song, although the mother produces several behaviours in synchrony with the infant also in the 2nd phrase of the song. Finally the GS2 mother produces most of her actions in synchrony with the infant in the 3rd phrase and the GS2 infant synchronises more frequently with his mother in the 2nd phrase.

Figure 5.40 Mothers' mean number of behaviours in synchrony with their infants for each phrase, as a function of context and age

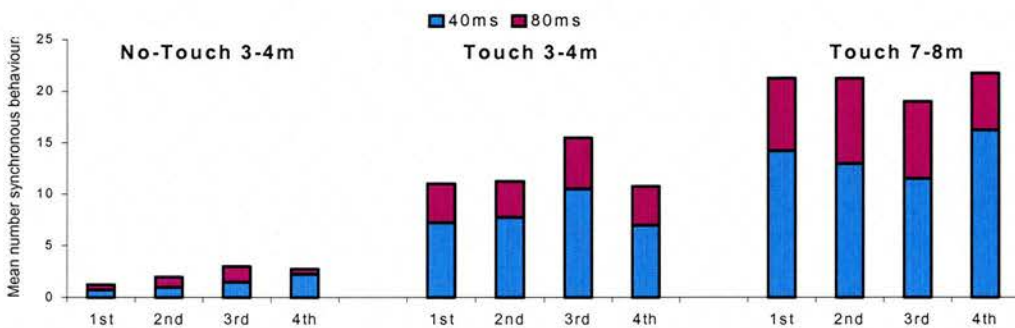
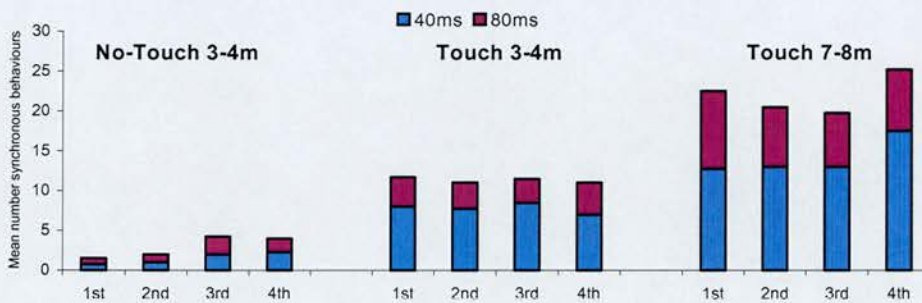


Figure 5.40 shows how the mothers' behaviours that are in synchrony with their infants' behaviours are distributed across phrases, for each of the three conditions. As in section

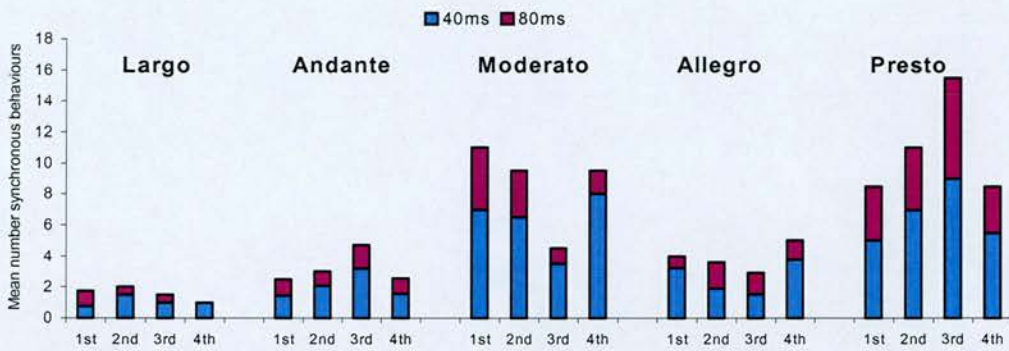
5.2.3, and Chapter 4, section 4.3.1, two two-way mixed ANOVAs (one for 40ms latency, and one for 80ms latency) were applied in order to investigate the effects of phrase and condition on the amount of behaviours mothers produce in synchrony with their infants' behaviours. The analysis of variance included one within factor, phrase (x4 levels, i.e., the number of phrases in the song) and one between factor, conditions (x3 levels, i.e., no-touch 3-4 months, touch 3-4 months, and touch 7-8 months). Again the analysis of variance was calculated on the number of the mothers' synchronous behaviours with their infants' across the phrases of the songs involving all song performances for each condition. Mothers do not show any significant effect of phrase or condition. There is also no significant interaction between phrase and condition at either latency.

Figure 5.41 Infants' mean number of behaviours in synchrony with their mothers for each phrase, as a function of context and age



As Figure 5.41 shows, the infants also synchronise differently across the phrases of the song as a function of condition. For instance, at 7-8 months they appear to match more frequently their mothers' behaviours in the 4th phrase of the song, whereas at 3-4 months they show little difference across the phrases of the song. Again two two-way mixed ANOVAs (one for 40ms latency and another for 80ms latency) examined the effects of phrase and of condition on the number of the infants' synchronous behaviours with their mothers. The analysis of variance included one within factor, phrase (x4 levels, i.e., number of phrases of the song) and one between factor, conditions (x3 levels, i.e., no-touch 3-4 months, touch 3-4 months and touch 7-8 months). The analysis of variance was carried out on the infants' number of synchronous behaviours with their mothers' behaviours across the phrases of all song performances occurring in each condition. Similarly to their mothers, infants also show no significant main effect of phrase as well as no main effect of condition. Moreover, there is no significant interaction between phrase and conditions at 40ms or 80ms latency.

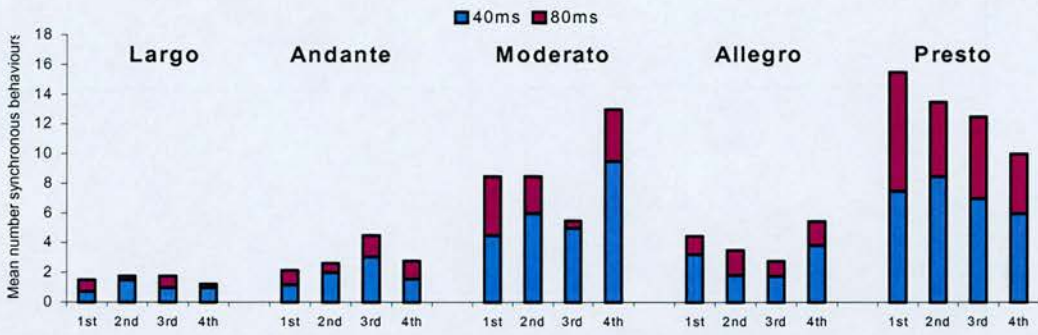
Figure 5.42 Mothers' mean number of behaviours in synchrony with their infants for each phrase, as a function of musical tempo



As Figure 5.42 shows, when the musical tempos of the songs are considered, mothers display great variation across the different tempos. For example, during the *largo* tempo mothers' synchronous behaviours seem evenly distributed in the phrases of the song. By contrast, during the *presto* tempo they most often produce behaviours in synchrony with their infants in the 3rd phrase of the song. In order to measure the effects of phrase and musical tempo on the mothers' behaviours in synchrony with those of the infants two two-way mixed ANOVAs (one for 40ms latency and another for 80ms latency) were used, in which there was one within factor, phrase (x4 levels, i.e., the number of phrases in the song) and one between factor, musical tempo (x5 levels, i.e., *largo*, *andante*, *moderato*, *allegro*, and *presto*). The analysis of variance was on the number of the mothers' synchronous behaviours with their infants' behaviours across the phrases of all song performances in each musical tempo. If the assumption of sphericity was not satisfied, Greenhouse-Geisser p values were used.

Although there is no main effect of phrase, there is a main effect of musical tempo at 40ms latency ($F(4, 30) = 4.11, p = .009$) and at 80ms latency ($F(4, 30) = 4.42, p = .006$). The mean number of synchronous behaviours mothers produce with their infants in the musical tempo is slightly higher at *presto* (6.62 at 40ms and 10.87 at 80ms) and *moderato* tempos (6.25 at 40ms and 8.62 at 80ms) compared to the others (*allegro*: 2.61 at 40ms and 3.88 at 80ms; *andante*: 2.07 at 40ms and 3.20 at 80ms; *largo*: 1.06 at 40ms and 1.56 at 80ms). Also there is a significant interaction between phrase and musical tempo at 40ms latency ($F(12, 90) = 2.30, p = .021$) and at 80ms latency ($F(12, 90) = 2.11, p = .024$). This suggests that the mothers synchronise more often with their infants in certain phrases than others according to the musical tempo of the song. For instance, they seem to match more often their infants in the 3rd phrase of the song with the *presto* and *andante* tempos whereas in the 4th phrase with the *allegro* tempo.

Figure 5.43 Infants' mean number of behaviours in synchrony with their mothers for each phrase, as a function of musical tempo



The infants also produce different amounts of synchronous behaviours with their mothers across the musical tempos of the songs. Similar to their mothers, infants display great contrast between *largo* and *presto* tempo songs. In fact, infants show very few synchronous behaviours almost evenly distributed in the phrases of the songs during the *largo* tempo songs. By contrast, at the *presto* tempo infants produce more synchronous behaviours and there is more variation in how these are distributed across the phrases of the songs. The number of infant behaviours in synchrony with those of the mothers across the phrases of the song was analysed as a function of musical tempo in two two-way mixed ANOVAs (one for 40ms latency and another for 80ms latency). In the analysis of variance, the within factor was phrase (x4 levels, i.e., the number of phrases in the song) whereas the between factor was musical tempo (x5 levels, i.e., *largo*, *andante*, *moderato*, *allegro*, and *presto*). The analysis of variance was on the infants' number of synchronous behaviours with their mothers in the phrases of all song performances occurring in each musical tempo. If the assumption of sphericity was not satisfied, Greenhouse-Geisser p values were used.

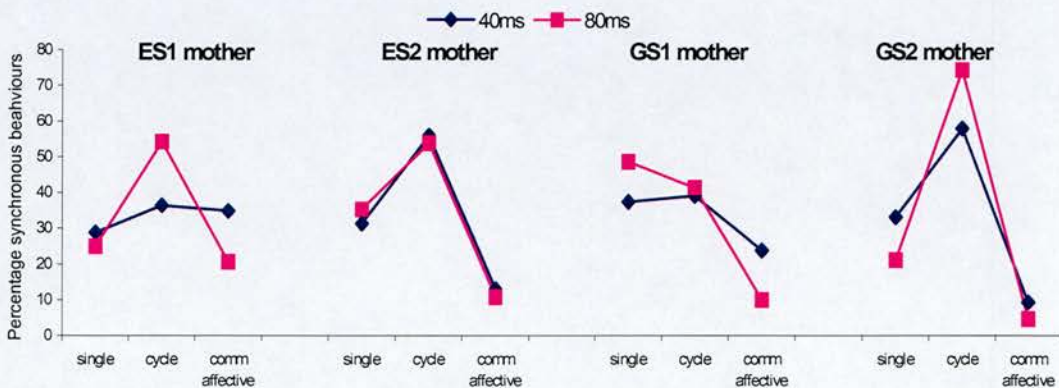
Similarly to the mothers, there is no significant effect of phrase on the number of behaviours infants produce in synchrony with their mothers' behaviours, but they show a significant main effect of musical tempo at 40ms latency ($F(4, 30) = 4.02, p = .010$) and at 80ms latency ($F(4, 30) = 5.79, p = .001$). Across the musical tempos of the songs, the mean number of synchronous behaviours infants produce with their mothers' behaviours is higher at *presto* (7.25 at 40ms and 12.87 at 80ms) and at *moderato* (6.25 at 40ms and 8.87 at 80ms) tempos compared to the others (*allegro*: 2.67 at 40ms and 4.06 at 80ms; *andante*: 1.96 at 40ms and 3.02 at 80ms; *largo*: 1.06 at 40ms and 1.56 at 80ms). Moreover, there is a trend towards a significant interaction between phrase and musical tempo at 40ms latency ($F(12, 90) = 1.87, p = .070$) and at 80ms latency ($F(12, 90) = 1.84, p = .079$). Bonferroni correction for multiple comparisons was applied on post-hoc comparisons and sets a new threshold for significance

at $p = .016$. Pairwise comparisons show a trend towards significance with the number of synchronous behaviours being higher in the 3rd phrase than in the other phrases of the song with the *andante* tempo at 80ms latency (t-tests two-tailed (paired) analysis: 3rd phrase vs 1st phrase, $t = 3.53$, $df = 13$, $p = .004$; 3rd phrase vs 2nd phrase, $t = 2.29$, $df = 13$, $p = ns$ (though approaching significance .039); 3rd phrase vs 4th phrase, $t = 2.79$, $df = 13$, $p = .015$). On the other hand, during the *allegro* and *moderato* tempos infants seem to synchronise more often with their mothers in the 4th phrase of the song.

5.3.3 Mothers' and infants' kind and category of synchronous behaviours

This section examines which behaviours mothers and infants produce when they synchronise with each other. In particular the focus is on: a) kind of synchronous behaviours mothers and infants produce, i.e., whether they constitute single gestures, cyclical patterns, or communicative-affective behaviours; and, b) category of behaviours in synchrony with each other, i.e., which part of the body the partners use to match with each other, (by head, body, limbs, in contact with the partner, or by toy). The next figures report the percentage of synchronous behaviours with the partner in relation to the overall amount of synchronous behaviours.

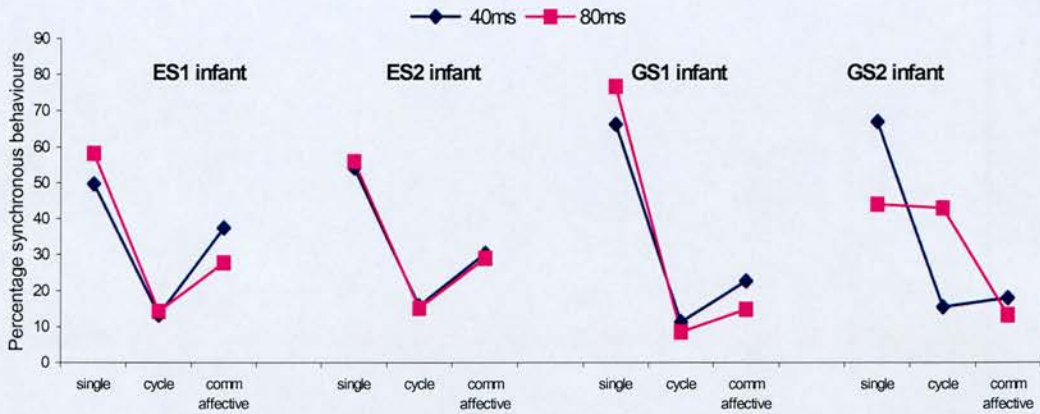
Figure 5.44 Mothers' kind of behaviours in synchrony with their infants, as a function of mother, collapsed across conditions



When the mothers produce synchronous actions with their infants, they mainly use cyclical patterns as shown in Figure 5.44. However, the GS1 mother matches several of her single gestures with her infant's participation especially at 80ms latency. The ES1 mother tends to use a higher percentage of communicative-affective behaviours to synchronise with her infant's movements than the other mothers do. It is interesting to note that, when a wider temporal window is considered, the mothers tend to display a higher amount of cyclical

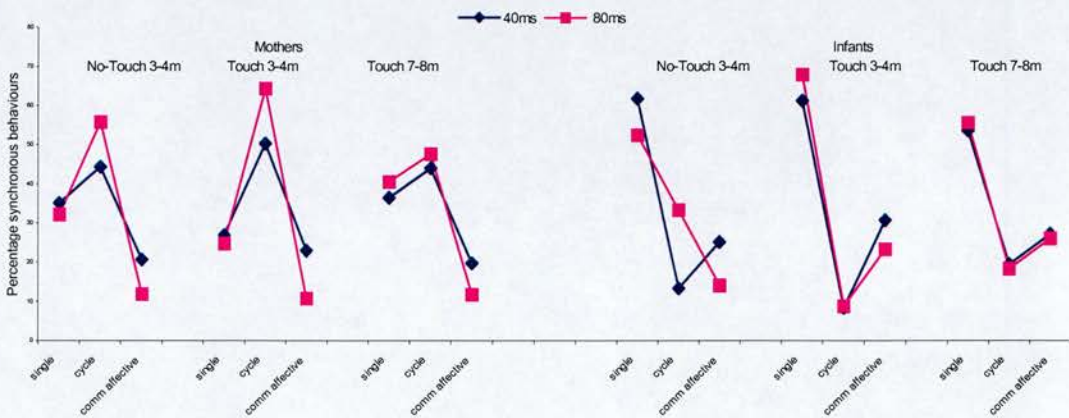
behaviours and less communicative-affective behaviours in synchrony with their infants compared to 40ms latency.

Figure 5.45 Infants' kind of behaviours in synchrony with their mothers, as a function of infant, collapsed across conditions



As Figure 5.45 shows, infants synchronise with their mothers' behaviours mostly through single gestures. However, at 80ms latency, it is interesting to observe that the GS2 infant performs similarly single and cyclical patterns when in synchrony with his mother. The other infants rarely display cyclical behaviours to match with their mothers' behaviours. In fact, they produce more communicative-affective behaviours to match their mothers' actions in comparison to cyclical behaviours.

Figure 5.46 Mothers' and infants' kind of behaviours in synchrony with each other, as a function of context and age

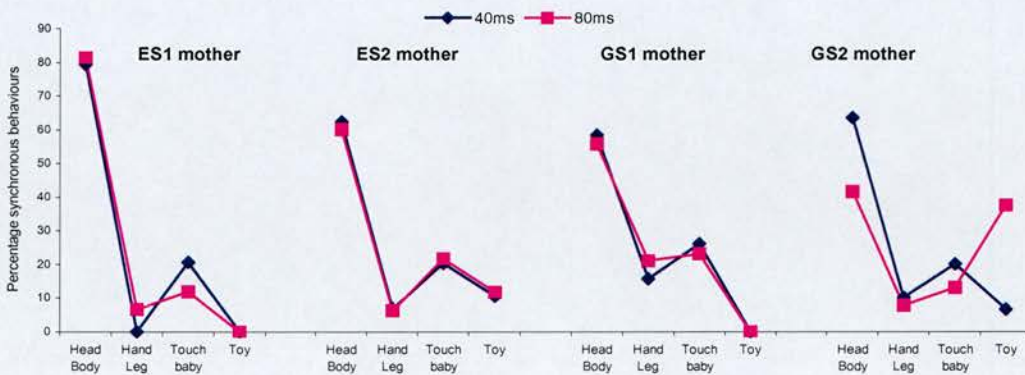


Across conditions, mothers use mostly cyclical patterns to synchronise with their infants' actions, especially at 80ms latency and during the touch context at 3-4 months. Moreover during the no-touch context at 3-4 months mothers produce a sizeable percentage of cyclical

behaviours in synchrony with their infants. However, it is interesting to observe that at 7-8 months mothers increase somewhat the amount of single gestures to synchronise with their infants. Finally, mothers rarely use communicative-affective behaviours to match with their infants' movements.

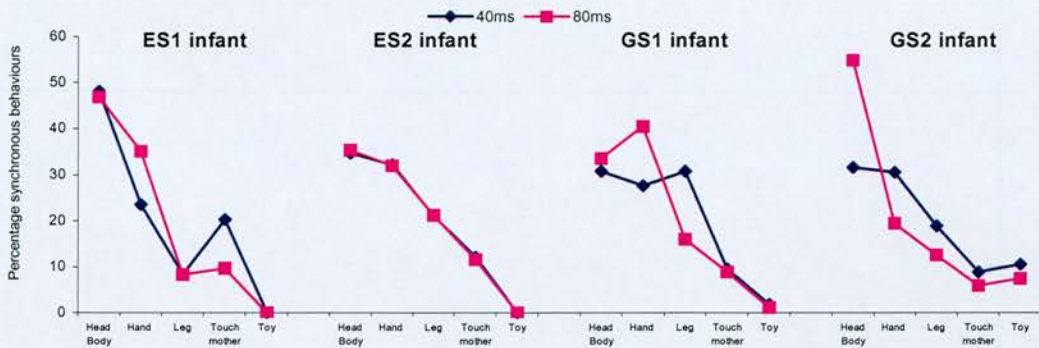
In general, infants appear to synchronise with their mothers' behaviours mostly through their single gestures. However, during the no-touch context at 3-4 months infants display a larger amount of cyclical gestures in synchrony with their mothers than in the touch context. At 7-8 months infants increase again the percentage of cyclical synchronous behaviours compared to 3-4 months

Figure 5.47 Mothers' category of behaviours in synchrony with their infants, as a function of mother, collapsed across conditions



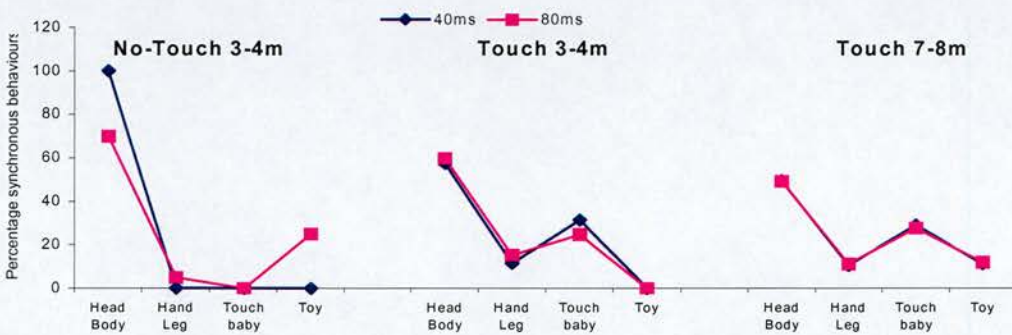
In Figure 5.47 it emerges that the majority of synchronous behaviours that mothers perform with their infants involve their head and body. At 40ms latency mothers sometime synchronise with their infants through gestures in contact with the infant. All the mothers appear to use occasionally their hands and legs to match with their infants' behaviours. In particular the ES1 mother uses her limbs to synchronise with her infant at 80ms but not at 40ms latency, whereas the GS1 mother more often uses her hands and legs to match with her infant's participation. Finally, only the ES2 and GS2 mothers use the toy to match with their infants' behaviours. In particular the GS2 mother appears to use very often the toy matching the infant's participation when 80ms latency is considered.

Figure 5.48 Infants' category of behaviours in synchrony with their mothers, as a function of infant, collapsed across conditions



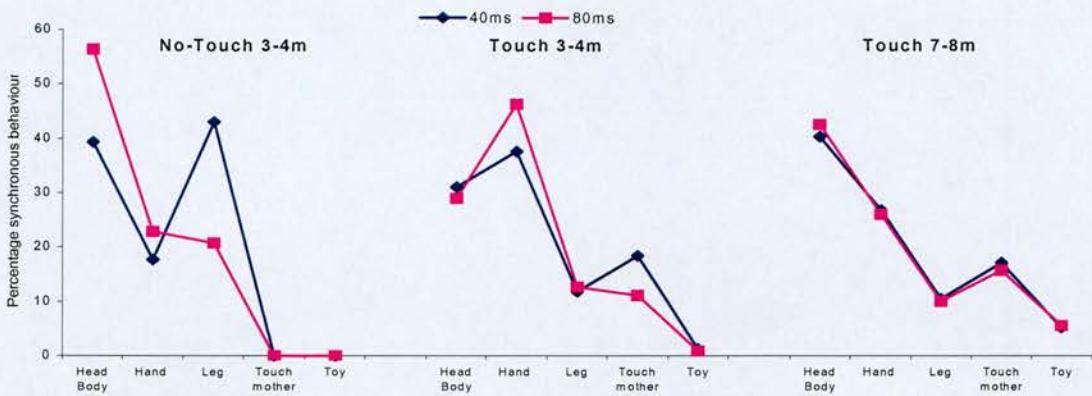
Similarly to their mothers, infants also synchronise with their mothers' behaviours mostly through their head and body behaviours. However, there are some individual differences. For instance, the GS1 infant performs mostly hand behaviours in synchrony with her mother's behaviours at 80ms latency, and leg behaviours at 40ms. The ES2 infant seems to perform similarly head and body as well as hand behaviours to synchronise with her mother's behaviours. Overall, infants use more often their hands than legs in synchrony with their mothers. Infants use only a few behaviours in contact with the mothers' behaviours to synchronise with them. Amongst all the infants, only the ES1 infant appears to perform more behaviours to synchronise with his mother than are actually in contact with her. Finally, only the GS2 infant uses toy movements in synchrony with his mother's participation.

Figure 5.49 Mothers' category of behaviours in synchrony with their infants, as a function of context and age



Although as noted previously, mothers synchronise with their infants' movements mostly through their head and body behaviours, during the no-touch context at 3-4 months mothers also use the toy in synchrony with their infants. With respect to age, mothers match their infants' participation through behaviours in contact with them. Moreover, at 7-8 months mothers again use a toy to synchronise with their infants.

Figure 5.50 Infants' category of behaviours in synchrony with their mothers, as a function of context and age



Although infants appear to synchronise with their mothers' participation through their head and body especially, as Figure 5.50 shows they also display some differences across conditions. For instance, during the no-touch 3-4 months context infants match with their mothers mostly with their leg behaviours at 40ms latency but not at 80ms latency. By contrast, in the touch context at 3-4 months infants match their mothers' mostly through hand behaviours. At 7-8 months infants still match with their mothers' participation through their hand behaviours, but they also move the toy synchronising with their mothers.

5.3.4 Discussion and conclusions regarding synchrony with each other

My findings demonstrate that mothers and infants synchronise with each other quite closely. Interestingly, the amount of synchronous behaviours the partners produce with each other is higher at 40ms than 80ms latency. Hence, when they synchronise with each other, the partners appear to cluster their behaviours closely at short latencies. The percentage of the mothers' synchronous behaviours with the infants' movements was predicted to be higher compared to the percentage of the infants' behaviours in synchrony with their mothers' but this is true only in the no-touch context. In fact, during the no-touch context at 3-4 months mothers produce a higher amount of behaviours in synchrony with their infants, whereas infants perform only a few synchronous behaviours with their mothers' actions. This suggests that in the absence of physical contact, mothers make more effort to match their infants' participation in order to attune with them in this unusual context. On the other hand, physical contact might facilitate the infants in attuning with their mothers. At 7-8 months mothers and infants produce a similar amount of synchronous behaviours with each other, suggesting that when infants are older the terms of the interaction are more balanced via the symmetry of their participation. Thus our findings suggest that, it is possible to pinpoint

changes in the patterns of interaction also during interaction with songs. When musical tempo is considered, it emerges that mothers synchronise less often with their infants during the *andante* and *allegro* tempos compared to the other tempos. Interestingly, during those tempos infants either produce a similar percentage of synchronous behaviours with their mothers i.e., *allegro*, or they perform more synchronous behaviours with their mothers' movements than their mothers do, i.e., during the *andante* tempo. Therefore it could be that during the *andante* and *allegro* tempos infants are more oriented towards their mothers, hence more likely to attune with them often matching their behaviours. Thus it could be that these two tempos favour the flow of the interaction between mothers and infants promoting their attunement. With respect to accuracy, it emerged that the precision of the partners' synchronous behaviours with each other is related to age and context. In fact, mothers and infants synchronise very accurately with each other during the no-touch context at 40ms but not at 80ms latency. Thus, in the absence of physical contact, mothers and infants are very focused on one another and match their behaviours tightly. At 7-8 months the partners of the dyad are less accurate compared to 3-4 months, but only at 80ms latency. This suggests that the partners of the dyad match more closely each other behaviours when infants are younger. By contrast, at 7-8 months mothers and infants may be less focused on each other and thus less precise. In fact, mother-infant interaction is less dyadic because external events are now incorporated into the interaction. Thus my findings have shown that, as with other non-musical dyadic activities, songs also become less precise in the dyad with age. With respect to the musical tempo, the partners of the dyad appear to match more precisely each other's behaviours during the *largo*, *andante* and *allegro* tempos compared to the others. Thus again *andante* and *allegro* emerge as tempos during which the partners can anticipate each others' participation more accurately. Interestingly during those tempos infants do not synchronise significantly with the beat at 80ms latency (see section 5.2.2). For the mothers, this only holds with the *andante* tempo. This suggests that with the *andante* and perhaps the *allegro* tempos both partners are more oriented towards each other than the music.

When the partners' synchronous behaviours with each other are considered in relation to the phrases of the song, they show great variation. Also when the mothers' and infants' behaviours in synchrony with the other's actions across the phrases of the songs are analysed as a function of condition, there is neither a significant effect of phrase, condition nor significant interaction between phrase and condition. These results suggest that mothers and infants modify their synchronous participation with the partner's behaviours across the phrases of the songs, irrespective of context and age. Moreover, if these results are compared

to the partners' level of activity across the phrases of the song as well as to their synchronous behaviours with the other partners across conditions, no relation emerges between these two aspects. In fact, in Chapter, 4 section 4.3.1, a significant effect of phrase was found, with mothers and infants producing more behaviours in the 1st phrase compared to the others. Thus they appear to synchronise with each other across the phrases of the song irrespective of the amount of behaviours they perform across the phrases of the song.

Interestingly, when the musical tempo of the songs is considered in relation to the partners' synchronous behaviours with each other across the phrases of the song, musical tempo appears to affect their synchronous participation more than conditions do. In fact, the analysis of variance showed a significant main effect of musical tempo which suggests that both mothers and infants modify significantly their number of synchronous behaviours with each other as a function of musical tempo. Moreover, there is a significant interaction between musical tempo and the partners' synchronous behaviours with each other across the phrases of the song. However, in the case of infants, there is only a trend towards significance. This suggests that the mothers especially, but less the infants, distribute their synchronous behaviours with the other's behaviours across the phrases of the song in relation to the musical tempo. Interestingly both partners appear to synchronise mostly with each other's behaviours in the 3rd phrase of the song during the *andante* tempo (infants show a trend towards significance at 80ms latency) and in the 4th phrase of the song *allegro* tempo songs. Perhaps with a larger group of participants this trend would reach significance. Thus it might be that during *andante* and *allegro* tempos both partners are more familiar with the temporal structure of the songs and participate accordingly. Alternatively, it could be that during those tempos mothers and infants are more capable of organising their behaviours in relation to the partner. Again when these results are compared with the partners' level of activity in the phrases of the song in relation to the musical tempo (see Chapter 4, section 4.3.1), it emerges that there is no relation between their level of activity and their synchronous behaviours with the partner across the phrases of the song.

As far as mothers' kinds of synchronous behaviours are concerned, apart from some variation, in the main they produce cyclical behaviours in synchrony with their infants' participation, as predicted. Therefore, once again, it emerges that cyclical behaviours are more used by the mothers to synchronise either with the beat or the infants' behaviours as well as to attune and communicate with their infants. When mothers match with their infants' participation the categories of behaviours they produce the most are movements of

their head and body. However, across conditions other patterns emerge. For instance, mothers move the toy to synchronise with their infants when there is little or no physical contact (only at 80ms latency). On the other hand, when there is physical contact mothers also attune with their infants' participation through behaviours in contact with them. However, contrary to my expectation, mothers produce mostly head and body behaviours in synchrony with their infants also at 7-8 months. Interestingly mothers seem to perform similar categories of behaviours when synchronising with the musical beat. Perhaps they can better co-ordinate these categories of behaviours in synchrony, either with the beat or with the infants' behaviours, when in interaction with songs. With respect to infants, as predicted, they are more likely to match with their mothers' participation through their single gestures. Thus similarly to when they synchronise with the musical beat of the songs, infants produce mostly single behaviours to match with their mothers' behaviours. Similarly to their mothers, infants frequently use their head and body behaviours to synchronise with their mothers', and less often their limbs, also when matching with the beat they showed the same pattern. However, there are some variations according to context and age. For instance, in the no-touch context they use mostly their head, body and leg to synchronise with their mothers. On the other hand, in the touch context at 3-4 months, infants use hands, head and body behaviours to attune with their mothers. Finally, at 7-8 months, infants match their mothers' activities mostly through head and body behaviours, and a much smaller percentage of their behaviours is devoted to moving a toy to synchronise with their mothers' movements. Therefore, this contradicts our hypothesis based on Moog's (1976) observation that infants will produce more specialised behaviours towards the end of the first year of life compared to the early months of life. Another interesting point is that when synchronising with their mothers' behaviours infants display several similarities with the category of behaviours they perform when synchronising with the beat across conditions. This is particularly true in relation to age, but less so with respect to context. However, there is also a major difference of category of synchronous behaviours between these two kinds of synchronisation. In fact, when infants synchronise with their mothers' behaviours they show around 20% of activity in contact with their mothers, whereas when they synchronise with the musical beat they produce a smaller percentage of synchronous behaviours in contact with their mothers. Thus infants appear to modify the category of synchronous behaviours they perform in relation to the kind of synchronisation involved.

In sum, as predicted, mothers and infants synchronise with each other's behaviours in interaction based around songs. Mothers were predicted to produce a higher percentage of

synchronous behaviours with their infants' than the percentage of the infants' behaviours in synchrony with their mothers'. But this pattern emerged only in the no-touch context. Context and age were predicted to affect the amount and accuracy of both partners' synchronous behaviours with each other. In fact, conditions affect both partners' synchronous participation with each other. Infants were expected to find it more difficult to match with their mothers' behaviours in the no-touch context than the touch one. In fact, infants display a very small percentage of synchronous behaviours with their mothers' in the absence of physical contact compared to the touch context. Although at 7-8 months infants were predicted to produce more synchronous behaviours with their mothers' than at 3-4 months, they do not show this pattern. No specific prediction was made in relation to the musical tempo of the songs and the partners' synchronisation with each other's behaviours. Mothers were found to produce less synchronous behaviours during the *andante* and *allegro* tempos whereas infants produce more synchronous behaviours with their mothers' during the *andante* and *moderato* tempos. Mothers were expected to produce mostly synchronous actions with the infants' which involved their body at 3-4 months, but actions in contact with the infant's body at 7-8 months. In fact, mothers synchronise with their infants' through head and body irrespective of context and age. Although infants were expected to increase their cyclical actions in synchrony with their mothers' at 7-8 months compared to 3-4 months, they do not show this pattern. Moreover, infants were expected to produce synchronous behaviours with different parts of their body at 3-4 months, and at 7-8 months they were expected to perform more limb activity. It turned out, however, that infants display mostly hand behaviours at 3-4 months and head and body behaviours at 7-8 months when synchronising with the mothers' behaviours. Although no prediction was made regarding the number of behaviours that mothers and infants might produce in synchrony with each other across the phrases of the song, a main significant effect of musical tempo emerged as well as a significant interaction between phrase and musical tempo, suggesting that tempo more than condition helps the partners of the dyad to organise their behaviours with each other across the phrases of the song.

5.4 Summary of the chapter

In this chapter, the mothers' and infants' synchronisation in relation to self, musical beat, and with the other partner of the dyad was discussed. In section 5.1, I examined the mothers' and infants' ability to co-ordinate their actions in self-synchrony during interaction with songs. Mothers and infants were found not to display a relation between amount and accuracy of self-synchronous behaviours. On the other hand, physical contact plays a role in

self-synchronisation in that both partners display more accuracy in the no-touch context. In the touch context, mothers are less precise but perform a higher amount of self-synchronous behaviours. At 7-8 months of age infants increase the amount of internally organised behaviours compared to 3-4 months. This suggests that the development of motor co-ordination in infants can also be observed in musical interaction with songs.

The partners' synchronisation with the musical beat was assessed in section 5.2 and it emerged that both partners synchronise with the beat. Mothers and infants show little variation across conditions, whereas in relation to musical tempo they appear to produce more synchronous behaviours with the beat when there are faster tempos. Both partners produce more synchronous behaviours with the beat at 40ms than at 80ms latency. Thus mothers and infants tend to cluster their behaviours closely on the beat rather than around it. With respect to musical tempo, both partners, but especially the infants produce more synchronous behaviours with the beat during faster tempo songs rather than slower ones. This could be explained by the fact that faster tempos are more easily processed, especially by infants. By contrast, slower tempos are more difficult to perceive and anticipate, with medium tempos serving yet other purposes. In fact, because medium tempos are perceived as neither too fast nor too slow, they may be more appropriate for setting the pace of the interaction. However, only the mothers show a significant effect of synchrony with the beat during *moderato* and *allegro* tempos. When accuracy with the musical beat is considered, infants display considerable accuracy in the touch context at 3-4 months, synchronising often exactly on the beat. Although the mothers tend to synchronise 40ms after the beat across conditions, in the touch context at 3-4 months they do so less, suggesting that at 3-4 months songs may be more integrated in the interaction than in the other conditions. When mothers and infants synchronise with the musical beat in the phrases of the song, they display more regularity than variation. However, when condition and musical tempo are considered there are some significant interactions. Therefore, both partners appear to modify their amount of synchronous behaviours with the beat across the phrases of the songs in relation to condition and musical tempo.

Interestingly the mothers synchronised significantly on the same beats that they lengthen when singing to their infants (see Chapter 3). This suggests that they emphasise the temporal structure of the song through different modalities irrespective of context and age. On the other hand, infants seem to understand their mothers' emphasis, synchronising on the same beats as stressed by them, i.e. 4th and 8th beats, as well as on the main downbeats, i.e., 1st and

5th beats, indicating that they are sensitive to their mothers' synchronisation on the upbeat. Therefore, infants not only perceive the segmentation offered by their mothers, but they also organise their behaviours accordingly. While mothers match the musical beat mainly through cyclical behaviours, their infants do so mostly with single gestures. A closer look at the kind of synchronous cyclical behaviours of the mothers reveals that they not only match the beat through vertically-oriented cycles but also vary the kind of cyclical behaviours in relation to context and age. Interestingly, in the touch context at 3-4 months, mothers produce several cycles in contact with the infant's limbs and at 7-8 months with the infant's body cycles. This indicates that mothers convey the temporal structure of the song through different means according to the infant's level of development. On the other hand, infants produce hand and leg cycles to match the beat of the song and they increase the variety of synchronous cyclical behaviours with the beat more at 7-8 months compared to 3-4 months. This suggests that with development infants not only become stronger and more internally co-ordinated, but they also organise their cyclical behaviours in relation to the temporal structure of the song in a similar way to their mothers. Finally, the analysis of the category of behaviours in synchrony with the beat shows that mothers use mostly head, body and in contact with infant behaviours. By contrast, infants perform mostly hand and leg synchronous behaviours at 3-4 months, but when older they use more often head and body to match with the beat. Therefore the mothers' and infants' synchronous participation with the beat in interaction with songs changes in relation to the dynamics of the interactive situation and to the infant's developmental stage.

Finally, in section 5.3 mothers and infants synchronisation with each other was discussed. Overall mothers produce a higher percentage of behaviours in synchrony with their infants' than the infants' percentage of synchronous behaviours with their mothers', in particular in the no-touch context. By contrast, in relation to age mothers and infants perform more similar amounts of synchronous behaviours with each other, especially at 7-8 months. This suggests that with age the terms of interaction change in such a way that the older infant contributes more to the harmonious flow of the interaction. It is likely that songs might help infants to co-ordinate their behaviours in tune with their mothers. Physical contact has an important effect on the accuracy of synchronisation between mothers and infants. In fact, in the absence of physical contact they are more focused on each other, especially at 40ms latency. Although mothers' and infants' synchronisation with each other across the phrases of the song occurs with great variation, as well as with respect to condition, this changes when musical tempo is considered. In fact, there is a main significant effect of musical tempo as

well as a significant interaction between musical tempo and the partners' behaviours in synchrony with each other in the phrases of the song. This suggests that musical tempo helps the partners to organise and co-ordinate their behaviours with one another according to the phrasing structure of the song. Interestingly both partners appear to synchronise more often with each other's behaviours in certain phrases than others. For instance, with the *andante* tempo the partners synchronise frequently in the 3rd phrase of the song (infants approaching significance) of the song and with the *allegro* tempo in the 4th phrase of the song. Mothers may sing these two tempos because infants are more familiar with them, allowing both partners to organise more easily their behaviours. It is also possible that organisation is better because mothers use those tempos more frequently. Moreover, mothers may sing songs more often at these tempos because the actual pace of the songs enables both partners to temporally organise their behaviours and interlock with each other. When one considers the kind of behaviours with which partners synchronise more frequently, it appears that mothers use mostly cyclical actions whereas infants use single gestures. However, in the no-touch context mothers synchronise more often through single gestures than cyclical actions. Finally, mothers produce mostly head and body behaviours across conditions whereas infants display different categories of behaviours as a function of age and context. Our findings have thus shown that mothers and infants display attunement in interaction with songs where temporal structure and specific musical tempos facilitate the interlocking of each other's participation allowing harmonious communication.

In the next chapter, I address the interaction of 4-5 month olds with taped music, focusing on the musical tempo of the taped music chosen by the mothers, as well as the partners' physical and communicative-affective behaviours and their synchronisation with self, the musical beat and the other partner.

CHAPTER SIX

Mother-infant interactions with taped music

6.1 Infants' sensitivity to taped music

The main focus of this thesis is on the interactional aspects of mothers' live songs. However, it was important to ascertain whether taped music would yield similar results, and whether the mother's own favourite taped music would impact differently on the interaction compared to the infant's favourite taped music. Ascertaining this would help us to understand more about the nature of mother-infant musical interaction, in particular whether singing or playing taped music with infants would yield similar effects in musical interaction. First it is important to note that infants are indeed sensitive to taped music, even very early in life. Pregnant mothers often report different reactions from their foetus to various kinds of music (Lecaunet, 1996). The variety of responses shown by the foetus might be due to differences in pitch, loudness, and tempo as well as to the behavioural state of the infant. Studies by Hepper (1988) and Feijoo (1981) showed that 4-5 day-old infants respond to taped musical stimuli to which they have been exposed during the last 3 months of gestation, by becoming calmer and more attentive. This response was displayed both by infants who listened to the bassoon part of Prokofiev's Peter and the Wolf (Feijoo, 1981) as well as those who listened to the musical theme of their mothers' favourite soap opera, Neighbours (Hepper, 1988). Furthermore, Woodward (1992) provoked a 93% heart-beat acceleration in a group of foetuses, by playing Bach's organ prelude in an air-coupled procedure for 15 seconds at 100dB. Thus, both before and after birth infants display a reaction to musical stimuli which can also be prompted by their mothers' preferences. In fact, the mother's psychobiological response to music depends not only of the kind of music but also on the mother's history (Lecaunet, 1996). In a study by Zimmer et al. (1982) a piece of either classical or pop music was played through headphones to pregnant mothers. While the mother listened to these pieces of music, their foetuses displayed increased body movements and decreased respiratory actions than during the silent times. This reaction was more marked when the mother's favourite music was played. Therefore, contrary to the claim by Trehub and Trainor (1993) that infants are naive listeners, newborns are already sensitive to musical stimuli, displaying preferences for music they listened to when in the womb. On the other hand, Trehub and Trainor (1998) found that infants display musical preferences for certain musical patterns which they call 'good', and which they suggested are

based on possible music universals. According to the authors infants prefer those patterns because they are more easily processed compared to others. These authors detected infants' preference on the basis of their attentional states, is it possible to identify infant's favourite music in contrast to the mother's favourite music in relation to their behavioural participation?

In this chapter mother-infant interaction while taped music is being played will be examined focusing on:

- 1) the musical tempos of the taped music that mothers select to play during interactions with their infants (section 6.2)
- 2) how mothers and infants participate in interactions in which taped music is played with respect to their level of activity and emotional behaviours, and infants' emotional states and degree of engagement (section 6.3)
- 3) mothers' and infants' synchronisation (section 6.4), in particular in respect to: self synchronisation (section 6.4.1), synchronisation with the musical beat (section 6.4.2), and synchronisation with the partner (section 6.4.3).
- 4) each of these points will be compared with the results on live songs in order to establish similarities and differences between interaction with taped music and interactions with songs. Therefore, together with the results of the analyses in Chapter 4, the qualitative data will be considered for generating suggestions for follow-up experiments.

6.2 Musical tempo of mother-infant interaction with taped music

In Chapter 3 the question was raised about the tempo used by the mother during musical interaction with her infant and whether she employs a consistent tempo throughout. Several authors reached different conclusions about the phenomenon of the mother's beat established in interaction. In fact, mothers have been found to produce repetitive runs of behaviours within another sequence of behaviours. It is within an 'episode of maintained engagement' that the mother establishes a beat (Stern, 1977; Stern et al., 1977; Trevarthen, 1979). In particular, through multimodal repetitive behaviours the mother sets a regular tempo allowing the infant to create expectancies from the interaction. Does this hold during interaction with taped music? In interaction with songs researchers have found that mothers use a tempo ranging between 500 and 700ms (Bergeson & Trehub, 1999; Trainor, 1996; Trevarthen, 1987). Interestingly, this range of tempos corresponds to the internal clock

hypothesised by Fraisse (1964). Will the mother use the same range of tempos, i.e., between 500 and 700ms during taped musical interaction with her infant?

On the basis of Fraisse's (1964, 1982) theory I hypothesised that the mothers would adopt a tempo around 500 to 700ms when in musical interaction with their infant, independently of the age of the infant and the context. In Chapter 3 this hypothesis was tested in musical interaction when mothers sing songs to their infants at different ages: 3-4 months and 7-8 months. At 3-4 months two contexts were compared during interaction with songs: no-touch versus touch. Then two ages were compared during the touch contexts in interaction with songs: 3-4 months versus 7-8 months. In this chapter the focus is on 4-5-month-old infants and compares the interactions with two kinds of taped music: the mother's favourite taped music versus the infant's favourite taped music. Within these two kinds of music two contexts are compared: no-touch versus touch. In the case of the infant's favourite music, the mother selected a piece of music that she regarded as the infant's favourite music. Mothers were asked to play the infant's favourite music first followed by the mother's favourite music, in two contexts: no-touch and touch. The touch context always followed the no-touch one, and the mothers were invited to keep to the same musical piece when the context changed. Although taped music does not allow the mother to modify the tempo as she would with songs, it is still relevant to determine the tempo she proposes through her choice of taped music in order to establish whether she reflects the temporal region suggested by Fraisse, i.e., between 500 and 700ms. In order to test this hypothesis the mean beat duration, standard error and modal tempo of the mother's favourite taped music and the infant's favourite taped music are analysed.

6.2.1 The mother's musical tempo in interaction with taped music

In this section the music chosen by the mother is examined, identifying the musical pieces selected and in particular the tempo of the music. The tempo of the taped music chosen by the mother was identified with the same procedure used for the songs, which is explained in Chapter 2 section 2.2.3. However, unlike the songs, taped music has not been described with respect to its temporal structure because it is more difficult to match the metre structure with the score of recorded music in order to identify its phrasing structure. The section of music analysed for this study occurred towards the beginning of the musical interaction, with the first 70-80s of the musical piece(s) for each condition selected. A total amount of 20 pieces of taped music was considered and analysed.

In Tables 6.1 and 6.2 the pieces of taped music chosen by the mothers as their infants' favourite music and their own favourite music respectively are listed.

Table 6.1 Infants' favourite music, according to their mothers

Mother	Title	Type
ES1	Old MacDonald (musical toy - only tune)	Children's song
ES2	Rebel Rebel (by David Bowie)	Pop-rock music
	Streams fill the river (unknown artist)	Gospel song
GS1	Sleepy eyes (by Michael Card)	Lullaby
	Eisg bhig (by Donnie MacLeod)	Children's song
GS2	Seinn seo (by Donnie MacLeod)	Gaelic children song
	Changegyu	Traditional folk song adapted for children
	Moo (by Donnie MacLeod)	Gaelic children song
	Uiseag Bheag Dhearg (by Donnie MacLeod)	Gaelic children song

The selection of the infant's favourite music suggests that infants enjoy music that is not strictly for children; indeed it also includes adult music and ranges from traditional folk to pop music, to lullaby. This suggests an influence of the mother's cultural background. For instance, the GS infants favour children's Gaelic music and traditional folk songs. On the other hand, the ES2 infant likes pop music and gospel which clearly belong to her mother's personal history. Finally, the ES1 infant prefers a children's song and this again seems to be part of her own experience.

Table 6.2 Mothers' favourite music

Mother	Title	Type
ES1	Stay by me (by A. Lennox)	Soft rock song
ES2	Desperados (unknown artist)	Romantic pop song
	Are you just waving or drowning (by Kirsty McCall)	Soft rock song
GS1	Fantasia on Green sleeves (by R. Vaughan Williams)	Classical music
	'Ailen Duin' (by Capercaillie)	Gaelic folk music
GS2	Gaelic hymns	Religious hymns - chanting
	Alasdair an Duir (by Fiona Kennedy)	Gaelic folk song
	From tv program about folk music (by Tom Sloss)	Gaelic folk song

The selection of the mother's favourite music indicates a variety of music which ranges from classical, to traditional folk to soft rock. Thus, the GS mothers prioritise traditional Gaelic music, even though GS1 also plays a piece of classical music. The GS2 mother's choice of Gaelic hymns particularly reflects her personal belief which is strictly related her culture.

In Tables 6.3 and 6.4 the musical tempos of the infant's favourite and mother's favourite taped music are reported respectively for the no-touch and touch contexts during interaction with 4-5 month-old infants.

Table 6.3 Musical tempos of the infant's and mother's favourite music in no-touch context at 4-5 months

Infant's music						Mother's music					
Mother	Title of music	Musical tempo	Mean beat duration	SE	Modal tempo	Mother	Title of music	Musical tempo	Mean beat tempo	SE	Modal tempo
ES1	Old MacDonald	allegro	0.49s	0.01s	allegro	ES1	Stay by me	andante	0.68s	0.00s	andante
	Old MacDonald	allegro	0.47s	0.01s	allegro						
ES2	Rebel Rebel	allegro	0.47s	0.00s	allegro	ES2	Desperados	allegro	0.43s	0.00s	allegro
GS1	Sleepy eyes	largo	1.46s	0.04s	largo	GS1	Fantasia on green sleeves	largo	1.62s	0.07s	largo
GS2	Changeyu	largo	1.03s	0.03s	largo	GS2	Gaelic hymns	adagio	0.81s	0.02s	adagio

During the no-touch context at 4-5 months the musical tempos of the infant's favourite music are *allegro* and *largo*. Interestingly, the ES mothers choose taped music with fast *allegro* tempo and the GS mothers taped music with a *largo* tempo. On the other hand, when the mother's favourite music is played in the no-touch context, the musical tempos range between *allegro* and *largo*. In particular the ES mothers choose moderate to fast tempos, with the ES1 mother using *andante* and the ES2 mother an *allegro* tempo. By contrast, the GS mothers choose slower tempos, with the GS1 mother using *largo* and the GS2 mother an *adagio* tempo. In sum, the ES mothers choose faster tempo music compared to the GS mothers.

Table 6.4 Musical tempos of the infant's and mother's favourite music in touch context at 4-5 months

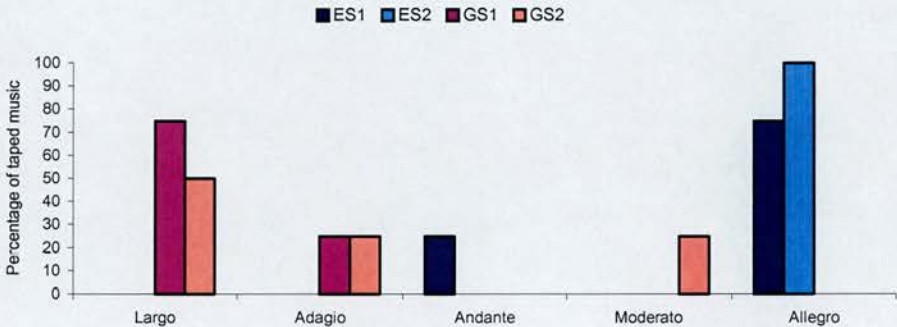
Infant's music						Mother's music					
Mother	Title of music	Musical tempo	Mean beat tempo	SE	Modal tempo	Mother	Title of music	Musical tempo	Mean beat tempo	SE	Modal tempo
ES1	Old MacDonald	allegro	0.47s	0.01s	allegro	ES1	Stay by me	andante	0.69s	0.00s	andante
	Old MacDonald	allegro	0.49s	0.01s	allegro						
	Old MacDonald	allegro	0.47s	0.01s	allegro						
	Old MacDonald	allegro	0.48s	0.01s	allegro						
	Old MacDonald	allegro	0.47s	0.01s	allegro						
ES2	Rebel Rebel	allegro	0.47s	0.00s	allegro	ES2	Desperados	allegro	0.43s	0.00s	allegro
GS1	Sleepy eyes	largo	1.47s	0.02s	largo	GS1	Fantasia on green sleeves	adagio	0.80s	0.05s	andante
GS2	Moo	moderato	0.53s	0.00s	moderato	GS2	Gaelic hymns	largo	1s	0.01s	larghetto

When mothers play the infant's favourite music during the touch context, the musical tempos range between *allegro* and *largo*. The ES mothers continue to propose fast tempos, and the GS1 mother a *largo* tempo. However, with the infant's favourite music the GS2 mother changes her chosen tempo, using now a faster *moderato* tempo. On the other hand, when mothers play their own favourite music, similarly to the no-touch context the ES mothers use

moderate to fast tempos, i.e., the ES1 mother uses *andante* and the ES2 mother *allegro*. By contrast, the GS mothers play moderate to slow tempos. In fact, the GS1 mother uses an *adagio* tempo, although this is a variation of the same piece of music, whereas the GS2 mother plays a piece of music with a slower *largo* tempo.

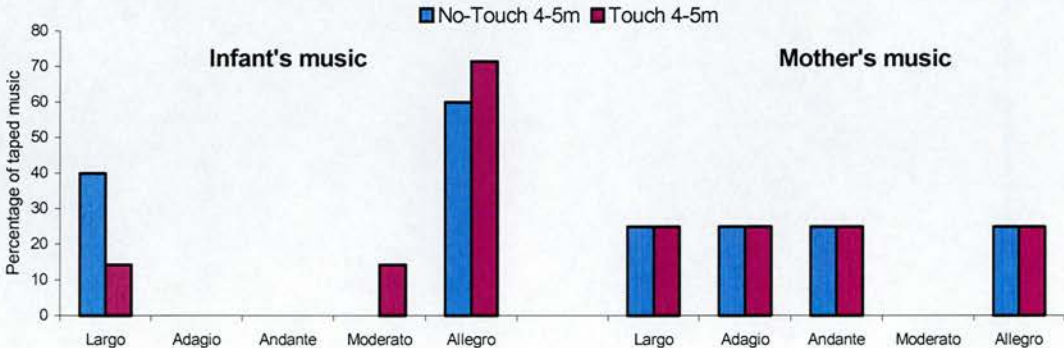
Figures 6.1 and 6.2 summarise the most common tempos used by the mothers when playing taped music in interaction with their infants. Figure 6.1 gives the percentage of each tempo of taped music played by the mothers, collapsed across contexts and type of music. Figure 6.2 shows the percentage of each musical tempo of taped music played in each context, as a function of the infant's favourite music and the mother's favourite music, collapsed across mothers.

Figure 6.1 Most common musical tempos expressed as percentage of overall taped music as a function of mother, collapsed across context and type of music



As Figure 6.1 shows the ES mothers use mostly *allegro* tempos, with only the ES1 mother using *andante* tempo. By contrast, the GS mothers play taped music mostly at *largo* tempo, with some *adagio* tempo and only the GS2 mother playing a *moderato* tempo.

Figure 6.2 Most common musical tempos expressed as a percentage of overall taped music as a function of context and type of music, collapsed across mothers



As Figure 6.2 shows, when playing the infant's favourite music mothers choose *allegro* and *largo* tempos in the no-touch context, but they tend to choose a higher percentage of faster tempos in the touch context. On the other hand, when they play their own favourite music mothers appear to select a variety of tempos between *allegro* and *largo* which do not differ as a function of physical contact.

6.2.2 Discussion and conclusions regarding the musical tempo of taped music

During interaction with taped music the infant's favourite music as well as the mother's favourite music reflect the mothers' personal history and their cultural background. In fact, the infant's favourite music includes children's songs and lullabies, traditional folk and pop music. Similarly, the music selected as the mother's favourite music includes a variety of other styles: classical, soft pop and rock music, as well as traditional folk music and religious hymns. Thus music is not only a way to play together, share feelings and emotions, but also an occasion to participate in the mother's personal history and cultural background. In particular, the ES dyads' music mirrors their personal history, whereas the GS2 dyad's music reflects their cultural background. This is consistent with the views of Deng (1973) and Kartomi (1980) who argue that music is a vehicle of enculturation which conveys socio-cultural elements at a base of the society and its members.

It thus seems that when they select taped music, the mothers choose music from their cultural background, i.e., the GS2 mother, as well as their personal background, i.e., the ES mothers, in a similar way to their selection of live songs for their infants. Therefore songs and taped music appear to reflect the mothers' heritage. However, despite this similarity between these two forms of music, there are also some differences. For instance, when playing taped music to her infant the GS1 mother uses classical music and an English lullaby thus presenting different musical pieces. In other words, the GS1 mother does not seem to convey her linguistic background through her taped music selection. Moreover, when the ES2 and GS2 mothers sang to their infants, they modified the lyrics of the songs to insert the name of their infant so to personalise the singing event. By contrast, mothers never adjusted the lyrics of taped music to include the infant's name. Thus it seems that live songs reflect the mothers' background more precisely, allowing them to render the musical event more personal .

The musical tempos of the music selected by the mothers range between *largo* (1470ms) and *allegro* (430ms). In particular, the ES mothers play *allegro* and *andante* tempos, whereas the

GS mothers prefer *largo*, *adagio* and *moderato* tempos. Perhaps the ES mothers choose medium to fast tempos to stimulate their infants in a fast interaction, whereas the GS mothers choose slower tempos probably to calm their infants in a slow interaction. During both contexts with the infant's favourite music mothers choose musical pieces at *allegro*, *moderato* and *largo* tempos, whereas the mother's favourite music gives rise to musical pieces between *largo* to *allegro* tempos (but not *moderato*). This is contrary to Fraisse (1964, 1982) who suggested that mothers would use musical tempos ranging between 500ms and 700ms, because this represents the succession of stimuli which appears more natural, neither too slow nor too fast. In fact, the musical tempos chosen by the mothers range between 430ms and 1620ms. Interestingly mothers play faster tempos for their infant's favourite music and slower tempos music for their own favourite music. These results seem to be better explained by Jones' Dynamic Attending theory in which she suggests that the Reference Period slows with age and experience in accordance with the infant's biological cycles (1976, 1987). Thus, infants should be more sensitive to faster tempos with adults showing the opposite pattern. In particular age and experience are likely to be the reason for the preference for slower tempos. Mothers could be using faster tempos with their infants as part of their intuitive parenting (Papousek, 1996) which helps them provide the most appropriate musical stimulation for the infant.

Also in the chapters discussing interaction with live songs, I found that mothers use a variety of musical tempos, ranging between *largo* and *presto*, which go beyond Fraisse's tempos. Therefore for both kinds of musical interactions, mothers use different tempos which range from slow to fast. On the other hand, in interaction with live songs mothers usually performed more than one tempo in each condition, whereas in interaction with taped music there was usually one tempo per condition. In fact, the mothers could not change the tempo of the music until the piece of music had ended. Because it emerged that musical tempo is not only important for maintaining homeostasis in the infant, but also serves to attract the infant's attention, it appears that songs which usually last less than a minute may be more appropriate than a piece of taped music which lasts several minutes. In fact, the songs give to more flexibility on the part of mothers than a piece of taped music, e.g., they can even modify tempo within the same song. Therefore songs may be more suitable in interaction with infants because they can be rapidly adjusted to the infants' changing states.

6.3 How do mother and infant participate in an interaction with taped music?

If little research has been done on songs with infants, even less has been carried out to understand the relation between taped music and infant behaviours. The studies that do exist point to different infant reactions according to the type of taped music. For instance, Trevarthen et al. (1981) noted that 4-month-old infants display appreciation for dance and instrumental music and turn their attention towards the source of music. However, this was based on pure observation with no quantitative analysis. An experimental approach comes from Trehub (1993) who exposed a group of 9-13 month-old infants to two pieces of music: 1) McNamara's Band, a lively and rhythmic version, and 2) Traumeri, a slow and melodic version. When the videotapes were coded, it emerged that the infants displayed more head and body bouncing, i.e., vertical motion, when listening to the rhythmical McNamara's Band compared to the melodic Traumeri music. Work in progress on the relevance of taped music in interaction between infants and their mothers comes from Mazokopaki (2000). She studied a group of 15 dyads (infants ranging from 2 to 10 months) and a taped, traditional Greek baby song played to them under different conditions: when alone with the taped music, and during free play with the mother. Her preliminary findings suggest that after pausing and directing their attention to the source of music, infants started moving their body and limbs in rhythmic activity.

Although these studies report levels of activity in infants when exposed to taped music, they fail to provide details of the mother-infant interaction in such a context. Moreover, they do not compare the emotional value of the type of taped music used and the importance of physical contact. What is the level of activity and rhythmical behaviours of 4-5-month-old infants during interaction with taped music when listening to their own favourite music compared to their mother's favourite music? What is the mother's level of activity and rhythmical behaviours with the two kinds of music? Is the level of the infant's and mother's activity affected by physical contact with the mother? Does the musical tempo affect the mother's and the infant's level of activity and cyclical behaviours during interaction with taped music? Which kind of cyclical behaviours do mothers and infants perform during interaction with taped music?

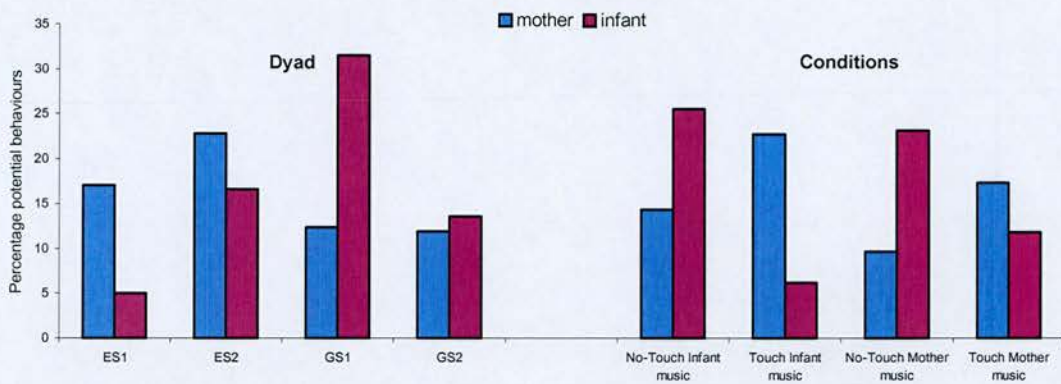
I hypothesise that when listening to their own favourite music, infants will move more often and produce more rhythmical patterns compared to when they listen to their mother's favourite music. This is based on the assumption that the mothers use the infant's music to

play with their infants, whereas they use their own music for relaxing. Similarly to the earlier study with songs, physical contact is predicted to affect the infants' participation in interaction with taped music. In fact, I hypothesise that infants will move less often during the no-touch context compared to the touch context, both with infant's and the mother's favourite music. In contrast, mothers are expected to participate in similar ways with both kinds of music, or, at most, they will show slightly more actions and rhythms during the infant's music compared to their own. Moreover, the mothers will show comparable levels of activity across the two musical contexts as a function of physical contact. Regarding the musical tempo of the taped music and partners' level of activity and cyclical behaviours, no specific prediction is made. In order to test the above hypotheses, I used the dataset of interaction with taped music presented in section 6.2.1. This was obtained by asking the mothers to play the infant's favourite music and their own favourite music to their 4-5 month-old infants in two contexts: no-touch and touch. The level of physical activity and cyclical behaviours performed by mother and infant during the infant's favourite music compared to the mother's favourite music have been analysed.

6.3.1 The partners' physical behaviours in interaction with taped music

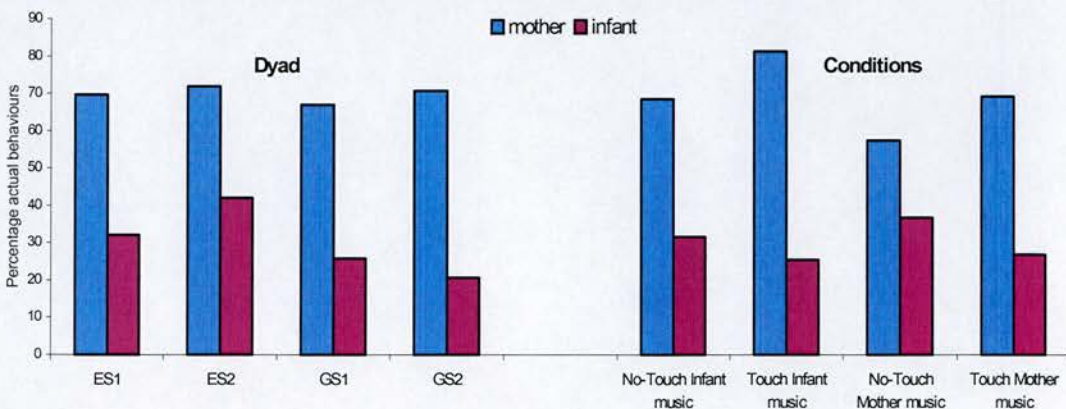
In this section, I examine the mother's and the infant's level of physical activity and cyclical behaviours performed during interaction with taped music. Cyclical behaviours are of particular interest because they represent the rhythmical component of their participation. The procedure for measuring the partners' level of activity and cyclical behaviours is explained in Chapter 2, section 2.3.1.1. In particular, Figures 6.3 and 6.5 below illustrate the partners' level of activity, expressed as a percentage of the potential amount of activity performed by the partners during each interaction. In fact, mothers and infants could move different parts of the body at the same time. Figures 6.4 and 6.6 display the amount of cyclical behaviours the partners produce, expressed as a percentage of the overall amount of actual activity.

Figure 6.3 Mothers' and infants' overall level of activity expressed as a percentage of their potential amount of activity as a function of dyad and conditions



As Figure 6.3 shows, during interaction with taped music the partners of the dyad show different levels of activity. Interestingly, the ES and GS dyads display two different patterns. The mothers of the ES dyads produce a higher level of activity compared to the GS mother and their infants, whereas the GS mothers produce less behaviours compared to their infants. With respect to conditions, during the infant's favourite music mothers perform more behaviours in both contexts compared to their own favourite music. Moreover, mothers are more active in the touch context compared to the no-touch one with both types of music. On the other hand, infants produce a higher level of activity in the no-touch contexts with both types of music compared to the touch contexts. In the touch contexts, infants are more active during the mother's favourite music compared to their own music.

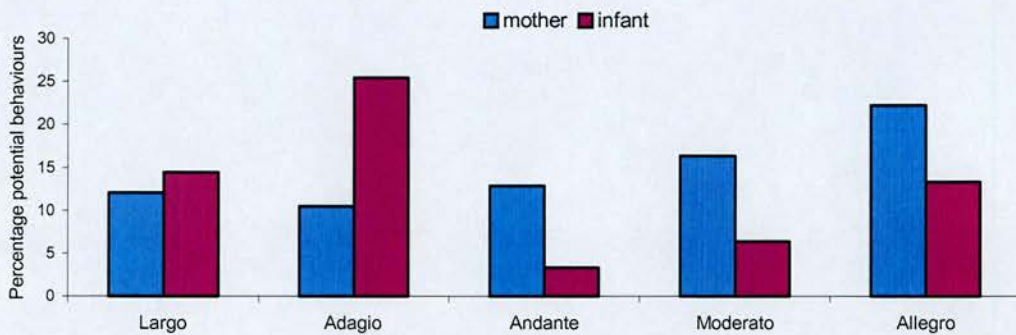
Figure 6.4 Mothers' and infants' overall amount of cyclical behaviours expressed as a percentage of total amount of their actual activity, as a function of dyad and conditions



As Figure 6.4 shows, overall the mothers produce a higher percentage of cyclical behaviours compared to their infants. In fact, they perform around 70% of cyclical behaviours, whereas infants produce only some 30% of their activity in cycles. It turns out that the ES infants display more cyclical behaviours than the GS infants, however. As far as conditions are

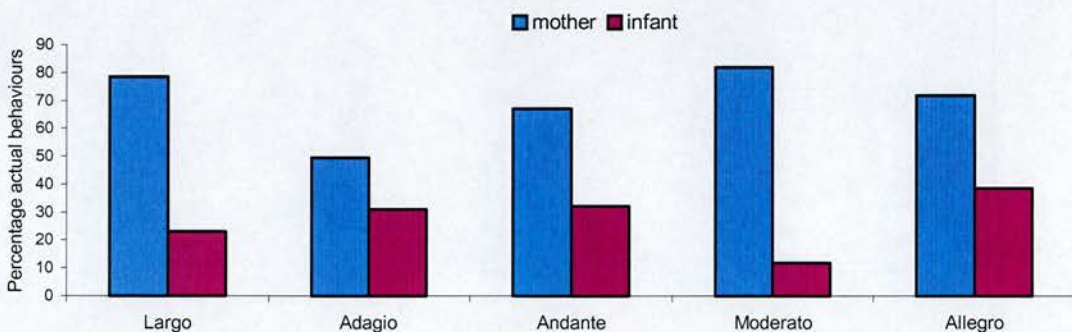
concerned, the mothers produce a higher percentage of cycles during the infant's favourite music compared to their own favourite music, especially in the touch context. On the other hand, infants display a higher level of cyclical activity during the no-touch contexts compared to the touch contexts, especially during the mother's favourite music.

Figure 6.5 Mothers' and infants' overall level of activity expressed as a percentage of potential amount of activity, as a function of musical tempo



In Figure 6.5 it appears that mothers perform a higher level of activity with faster rather than slower tempos. Moreover, during the *moderato* and *allegro* tempos mothers are more active compared to other tempos. By contrast, infants are more active with slower than faster tempo music. In fact, infants are extremely active during *adagio* and *largo* compared to the other tempos. Interestingly during the *andante* tempo both partners display low levels of activity, whereas during *allegro* tempo mothers and infants are quite active.

Figure 6.6 Mothers' and infants' overall amount of cyclical behaviours expressed as a percentage of total amount of actual activity, as a function of musical tempo



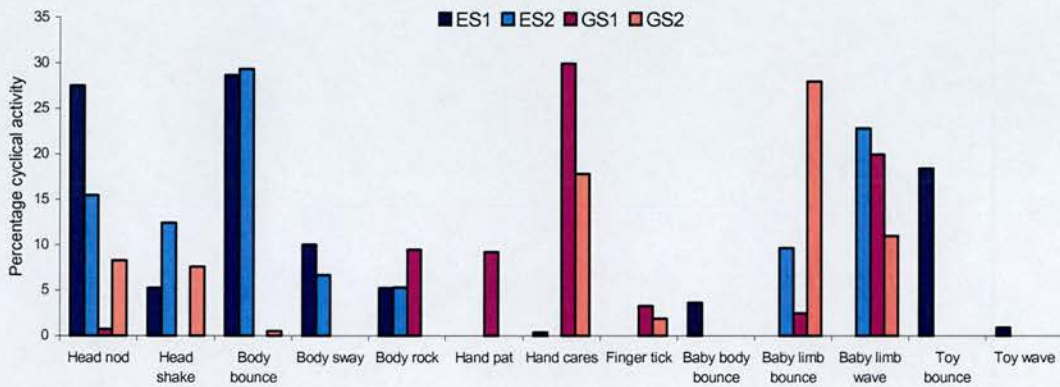
When the partners' cyclical activity is considered in relation to musical tempo, it emerges that the mothers still produce a higher percentage of cycles than their infants, in particular during the *largo* and *moderato* tempos. By contrast, with *adagio* tempo music mothers perform the least cyclical activity. With respect to infants, it appears that during the

moderato tempo infants produce the least amount of cyclical behaviours. During the other musical tempos infants do not show any relevant differences in their percentage of cyclical behaviours.

6.3.1.1 Mothers' and infants' type of cyclical behaviours

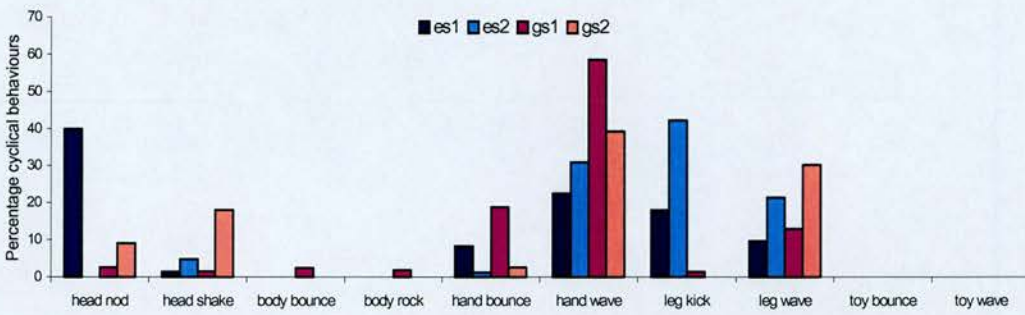
In this section, the most commonly performed cyclical behaviours that mothers and infants produce during interaction with taped music are examined. In the following figures, the mother's and the infant's types of cyclical behaviours are expressed as a percentage of their overall cyclical activity. Because mothers produce a large variety of cycles, with some being more part of their personal repertoire than others, the figures report only the most common cycles across mothers. On the other hand, because infants produce a smaller variety of cycles compared to their mothers, all their types of cycles are shown.

Figure 6.7 Mothers' types of cyclical activity as a percentage of total amount of cyclical behaviours as a function of mother, collapsed across conditions



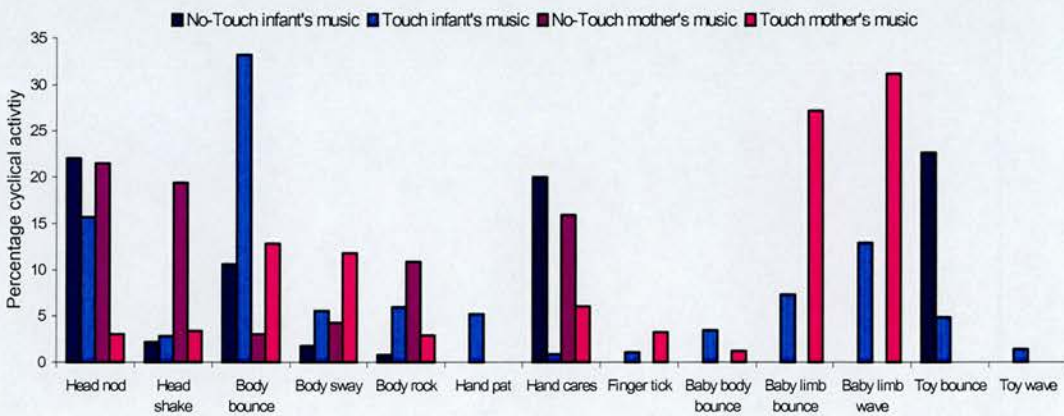
As Figure 6.7 shows mothers produce a great variety of cyclical behaviours in interaction with taped music. However, some cycles are shared by all mothers whereas others are less so. For instance, all mothers produce head nodding, whereas baby body bouncing and toy cycles are performed only by the ES1 mother. Another interesting aspect is that even on the kind of cyclical patterns they perform the GS and ES mothers appear divided. For instance, the ES mothers often bounce and sway their bodies, and the ES1 mother also moves the toy in cycles, whereas the GS mothers produce several hand and finger cycles. Thus, the ES mothers produce mostly cycles with their own body and few cycles in contact with the infant's limbs and body. The GS mothers, by contrast, display a large variety of cycles in contact with their infants, touching them with their hand and finger and moving their limbs.

Figure 6.8 Infants' type of cyclical activity as a percentage of total amount of cyclical behaviours as a function of infant, collapsed across conditions



In contrast to their mothers, infants appear to produce more similar kinds of cycles, and they do not move the toy in cycles during taped music interaction (see Figure 6.8). The most common cycles all infants produce are hand waving and leg waving, hence horizontally-oriented cycles. However, it is interesting to note that the GS infants also perform several hand cycles, and the ES infants leg kicking. Finally, all infants appear to produce a few head cycles but only the GS1 infant moves her body in cycles.

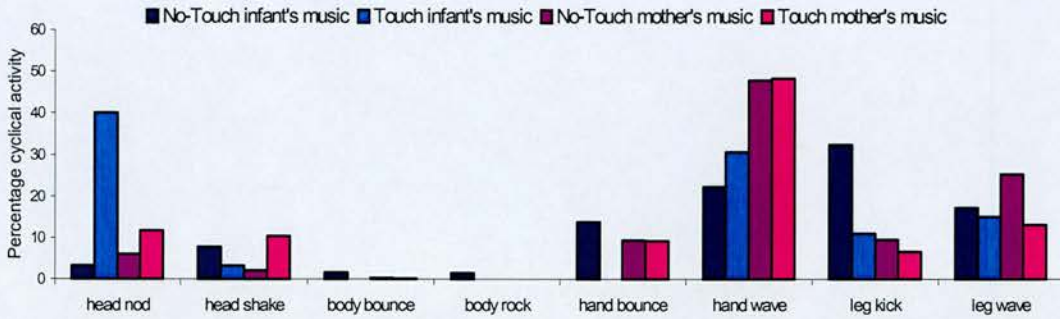
Figure 6.9 Mothers' type of cyclical activity expressed as a percentage of the total amount of cyclical behaviours, as a function of condition



In Figure 6.9 it emerges that during the no-touch context with both kinds of music mothers produce frequent head nodding and hand caressing. However, in the no-touch context with the infant's favourite music mothers also bounce the toy and their body, whereas with the mother's favourite music mothers shake their head. In the touch context with the infant's favourite music, mothers display a lot of head nodding and body bouncing as well as a few cycles in contact with the infant's limbs. On the other hand, during the mother's favourite

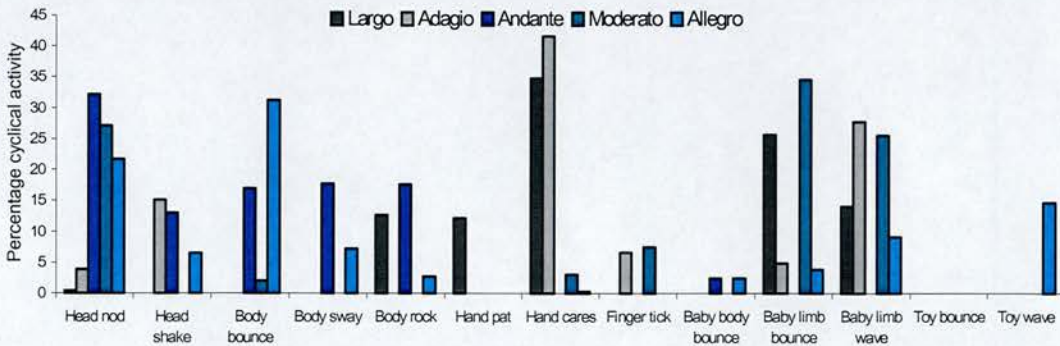
music in the touch context, mothers still bounce and sway their body, but the majority of cycles consist of bouncing and waving the infant's limb.

Figure 6.10 Infants' type of cyclical activity expressed as a percentage of total amount of cyclical behaviours, as a function of condition



Overall infants appear to produce mostly limb as well as head cycles during both contexts and with both kinds of music (see Figure 6.10). However, during the infant's favourite music infants produce more vertically-oriented cycles, like head nodding and leg kicking compared to the mother's favourite music. In fact, in the latter, infants perform mostly hand and leg waving. As far as context is concerned, during both no-touch contexts infants display several limb cycles, especially leg kicking and hand bouncing. Whereas, during both touch contexts infants produce numerous head nodding as well as hand and leg waving.

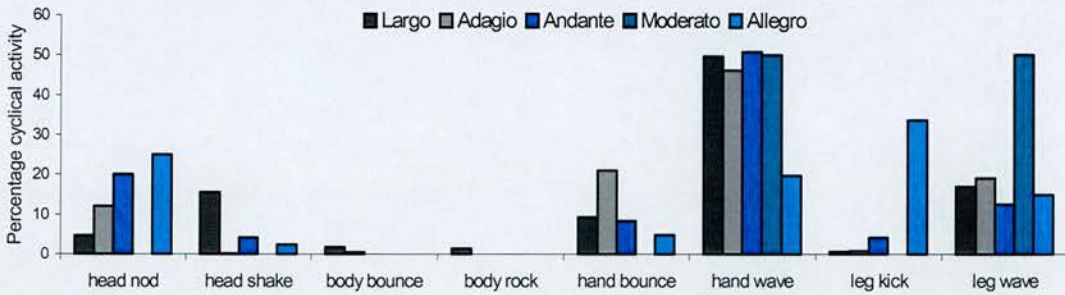
Figure 6.11 Mothers' cyclical activity expressed as a percentage of total amount of cyclical behaviours, as a function of musical tempo



Overall it seems that mothers perform cyclical patterns at a variety of musical tempos, i.e., there is no strict relation between musical tempo and cycles, as Figure 6.11 shows. For instance, head nodding and cycles in contact with baby limbs occur at different tempos. However, it is interesting to note that some cycles happen more frequently with certain

tempos than others. For instance, during slow tempo music, i.e., *largo* and *adagio*, mothers appear to produce mostly hand cycles. On the other hand, during *andante* and *allegro* tempos mothers mostly perform cycles with their own head and body but rarely in touch with their infants. With *moderato* tempo mothers continue often to nod their head nodding but also move the infant's limbs in cycles.

Figure 6.12 Infants' type of cyclical activity expressed as a percentage of total amount of cyclical behaviours, as a function of musical tempo



Interestingly, all infants perform hand and leg waving across all musical tempos (see Figure 6.12). In particular, hand waving is the mostly performed cycles whereas leg waving occurs less often, but especially with *moderato* tempo. On the other hand, vertically-oriented cycles appear to be related to specific musical tempos. For instance, leg kicking occurs mainly during *allegro* tempo, whereas hand bouncing is performed mostly during slow tempos and in particular *adagio*. Infants' body cycles are quite rare. However, they produce head nodding cycles especially during *allegro* and *andante* tempos. Finally head shaking occurs mostly with *largo* tempo.

6.3.2 Communicative-affective behaviours mothers and infants display during taped music?

Music is often considered to be a special medium for expressing emotions. Several authors have suggested that a close relation obtains between music and emotions (Meyer, 1956; Sloboda, 1991; Sloboda & Juslin, 2001). Rock et al. (1999) extended this concept, proposing that music might even be a more powerful medium than speech for communicating affect and emotion to infants. But how do the mothers express their emotions to infants and vice versa?

Research by Trehub and Zacharias (1998) observed that when they sing to their infants caregivers use a loving and smiling tone of voice. Although during interaction with taped

music mothers might sing along it is not the same as when they sing songs themselves. Will mothers therefore still display smiling expressions? Moreover, when exposed to live songs infants vocalise, show engagement and smiling (Holahan, 1987; Kelley & Sutton, 1987; Papousek & Papousek, 1981; Trehub, 1993). Will they show those behaviours in interaction with taped music? Although these studies observed such behaviours, they did not provide any quantitative measurements. During interaction with taped music, do infants touch their mothers? How much do they smile? To what extent do infants show active attempts to communicate? What are the features of the infant's emotional state and degree of engagement during interaction with taped music? Do the infant's communicative-affective behaviours, emotional state and degree of engagement vary according to the kind of music, i.e., their own favourite music versus their mother's favourite music? Does physical contact affect the infant's communicative-affective behaviours during taped music? What is the level of physical contact, affectionate gestures and smiling expressed by mothers during interaction with taped music? Does the mother show different levels of communicative-affective behaviours when listening to the infant's favourite music compared to her own? Does the mother's level of communicative-affective behaviours differ in relation to the presence or absence of physical contact?

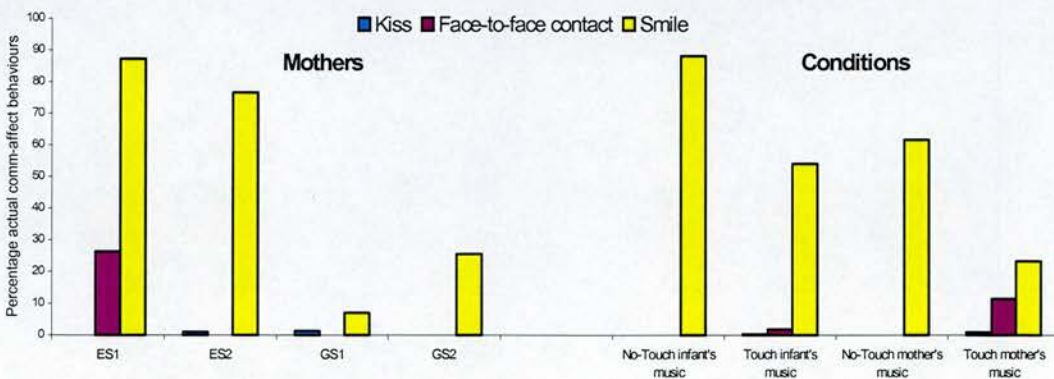
When infants are exposed to taped music, I hypothesise that they will show more smiling, vocalisation, contact with their mothers, positive state and degree of engagement during their own favourite music compared to the mother's favourite music. In particular, compared to the no-touch context, physical contact with their mothers will, I predict, enhance infants' positive communicative-affective states with both types of music. By contrast, during the mother's taped music in the no-touch context, it is predicted that infants will show the least smiling, vocalisation, contact with mothers, as well as less positive states and less degree of engagement compared to the touch context with the same kind of music. When mothers are exposed to taped music, it is hypothesised that they will show a similar amount of smiling and touching when listening to both the infant's favourite music as well as their own in both touch contexts. During both kinds of music, it is predicted that mothers will show more smiling during the no-touch context compared to the touch context. In fact, because of the unusual context mothers may try to reassure their infants by smiling longer.

In order to test these hypotheses I analysed the partners' communicative-affective behaviours performed in the interactions with taped music from the dataset presented in section 6.2.1. Mothers were asked to play to their 4-5-months old infants two types of music: the infant's

favourite music and their own favourite music, during no-touch and touch contexts. The mother's communicative-affective behaviours include: touching infant, kissing, face-to-face contact, and smiling. The infant's communicative-affective behaviours include: touching mother, touching self and touching a toy, smiling, and active attempt to communicate. The procedures to measure the partners' communicative-affective behaviours are presented in Chapter 2, section 2.3.1.2. Furthermore, only in the case of infants emotional states are analysed in terms of: very happy, happy, neutral, unhappy and very unhappy states, as well as the degree of engagement in terms of: high engagement, engagement, little engagement and no engagement. The infants' emotional states and degree of engagement are measured according to the criteria described in Chapter 2, section 2.3.1.3.

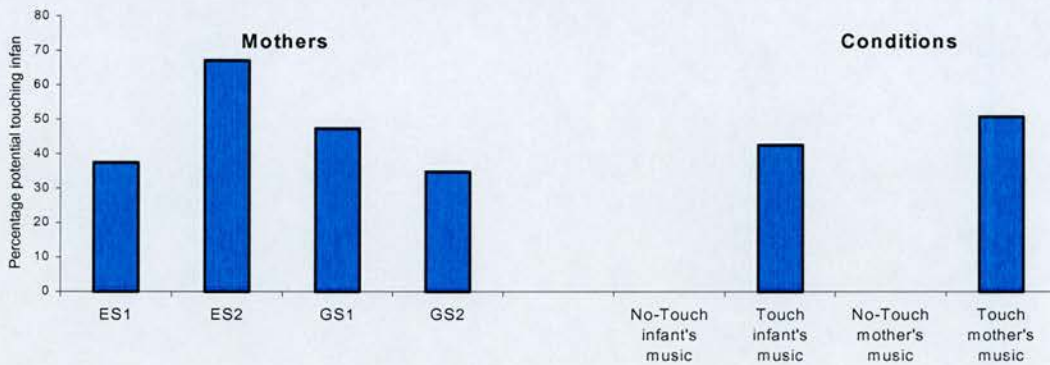
In this section, the mother's and infant's communicative-affective behaviours performed during musical interaction with taped music are examined. The mother's communicative-affective behaviours considered for this analysis are: touching infant, kissing, face-to-face contact and smiling. The infant's communicative-affective behaviours consist of: smiling, touching mother, self and toy. In particular in Figure 6.13, the amount of the mothers' kissing, face-to-face contact and smiling behaviours are expressed as a percentage of the total duration of the interaction. In Figure 6.14, the amount of mother touching the infant is expressed as a percentage of the mother's potential overall amount of touching her infant. The infants' communicative behaviours are displayed in Figures 6.15 and 6.16. In Figure 6.15, the infants' smiling and active communicative effort are expressed as a percentage of the total duration of the interaction, in Figure 6.16 the amount of the infants' touching the mother, self and toy is expressed as a percentage of the infant's overall amount of touching.

Figure 6.13 Mothers' kissing, face-to-face contact and smiling, expressed as a percentage of total duration of the interaction, as a function of mother and condition



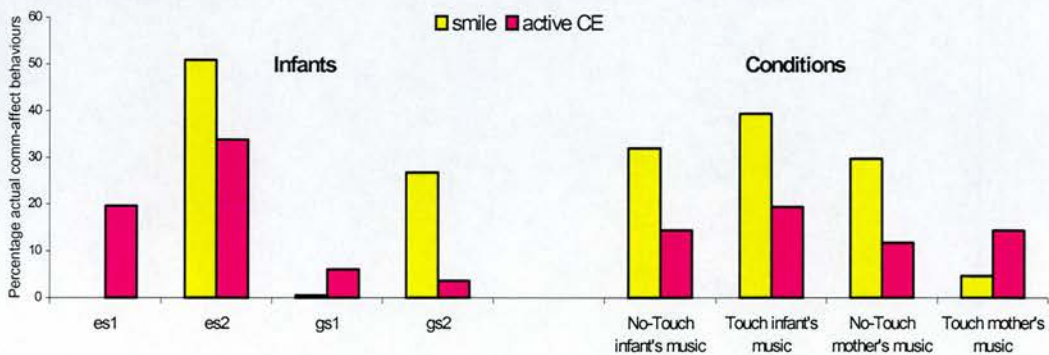
With respect to mothers, as Figure 6.13 shows, the ES and GS mothers show some differences regarding their communicative-affective behaviours. In fact, the ES mothers exhibit longer smiling compared to the GS mothers, and the ES1 mother also displays face-to-face contact. As far as conditions are concerned, it is interesting to observe that the mothers display longer smiling during the infant's favourite music compared to their own favourite music, especially in the no-touch contexts compared to the touch contexts. It is noteworthy that during the touch context with the mother's favourite music, although mothers smile less often compared to the infant's favourite music, they display more face-to-face contact.

Figure 6.14 Mothers' touching of their infants, expressed as a percentage of the potential overall amount of touching the infant, as a function of mother and condition



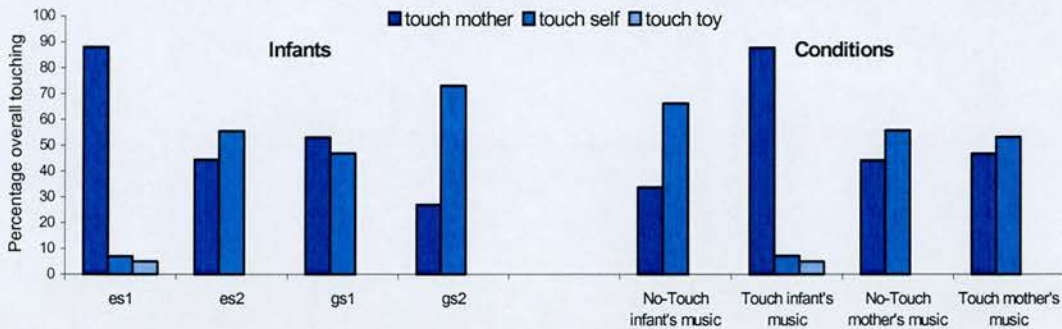
Aside from the ES2 mother who touches her infant very often, the other mothers display similar percentages of touching their infants. With respect to conditions, the mothers seem to touch their infants more frequently during the mother's favourite music than the infant's favourite music.

Figure 6.15 Infants' smiling and active communicative effort, expressed as a percentage of the total duration of the interaction, as a function of infant and condition



As Figure 6.15 shows, although all infants display some active communicative effort (CE), only the ES2 and GS2 infants smile. Both the ES infants appear to make more active attempt to communicate than the GS infants. With respect to conditions, infants smile longer and show slightly more active CE during the infant's favourite music compared to the mother's favourite music. Moreover, infants appear to smile more often and display more active CE in the touch context compared to the no-touch one but only with the infant's favourite music.

Figure 6.16 Infants' touching mother, self and toy, expressed as a percentage of total duration of touching, as a function of infant and condition



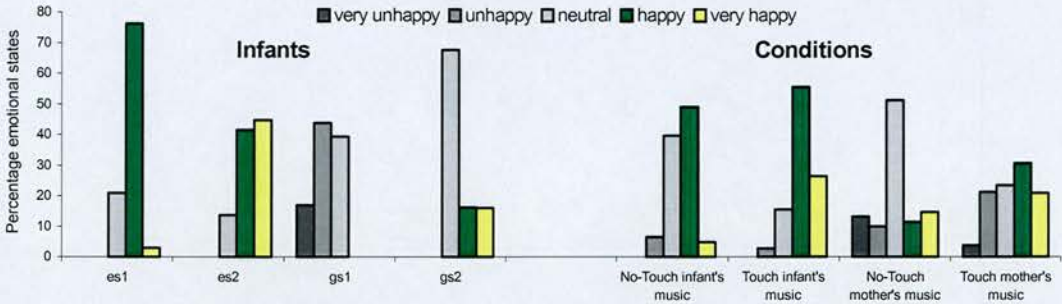
With respect to infants, in Figure 6.16 it emerges that all infants produce several contacts with their mothers, particularly the ES1 infant. They also perform a considerable amount of self-touch. The ES2 and GS2 infants especially, touch themselves more frequently than they touch their mothers. ES1 is the only infant who occasionally touches a toy. As far as conditions are concerned, it is interesting to note the considerable difference between the two types of music in relation to context. In fact, during the infant's favourite music in the no-touch context, infants touch themselves more often than they touch their mothers compared to the touch context. On the other hand, in the touch context with the infant's favourite music, infants display a considerable amount of touching of their mothers and very little self-touch compared to no-touch context. By contrast, when the mother's favourite music is played, infants do not display differences between contexts. In fact, during both contexts not only do infants touch themselves more than they touch their mothers but they also display similar amounts of touching overall.

6.3.3 Infants' emotional states and degree of engagement

This section examines the infants' emotional states and degree of engagement during musical interaction with taped music. The infants' emotional state and degree of engagement are expressed as a percentage of the overall duration of the interaction with taped music. The infants' emotional states include: very unhappy, unhappy, neutral, happy and very happy,

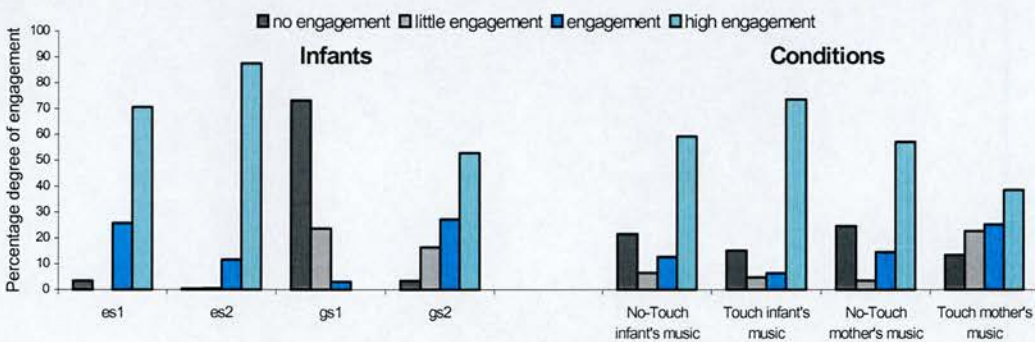
and these data are shown in Figure 6.17. The infants' degrees of engagement include: no engagement, little engagement, engagement, and high engagement, displayed in Figure 6.18. The procedure to assess the infant's emotional states and degree of engagement is explained in Chapter 2, section 2.3.4.

Figure 6.17 Infants' emotional states expressed as a percentage of the total duration of the interaction, as a function of infant and condition



When the infant's emotional states are considered, it emerges that the ES infants display positive states more frequently than the GS infants (see Figure 6.17). In fact, the GS1 infant displays mostly unhappy and neutral states. As far as conditions are concerned, although in the no-touch contexts infants display long neutral states with both kinds of music, they also display frequent happy states during the infant's favourite music compared to the mother's music. By contrast, in the touch context infants are often happy and very happy during the infant's favourite music, whereas during the mother's favourite music they display a mixture of states.

Figure 6.18 Infants' degree of engagement expressed as a percentage of the total duration of the interaction, as a function of infant and condition



When the infant's degree of engagement is considered, as Figure 6.18 shows, it appears that the ES infants display longer high engagement compared to the GS infants. In particular, the GS1 infant often appears not engaged during interaction with taped music. As far as conditions are concerned, during the no-touch contexts infants display similar degrees of

engagement with both kinds of music. However, in the touch contexts infants are much more often highly engaged during the infant's favourite music compared to the mother's favourite music.

6.3.4 Discussion and conclusions regarding mothers' and infants' participation in interaction with taped music

In their interaction with taped music, the ES mothers display a higher level of activity compared to the GS mothers. The reason for this could be due to the fact the ES mothers use faster tempo music compared to the GS mothers who use medium to slow tempos. On the other hand, the ES infants do not show a higher level of activity compared to the GS infants. In the infants' case it seems that their level of activity is not related to the tempos of the music. However, when their cyclical activity is considered, it emerges that the ES infants produce more cycles compared to the GS infants and again this could be related to the musical tempos. In fact, the fast tempos of the music played by their mothers could prompt their cyclical participation. As suggested by Trehub (1993), more cyclical actions occur in 9-13-month-old infants when exposed to a lively rhythmic music compared to a melodic one. As far as conditions are concerned, the mothers produce a higher level of activity and more cyclical actions during the infant's favourite music compared to their own music. As predicted, mothers are slightly more active and cyclical in their participation during the infant's favourite music compared to their own. The reason for this participation could be due to the fact that they use faster musical tempos and hence are prompted to be more dynamic. But it could also be that mothers use richer activity with several cycles to emphasise that this is their infants' 'special' music and the rhythmical activity serves to attract and maintain their attention as well as communicate with them. Although it was expected that mothers would show similar moderate participation in the contexts independently of physical contact, they displayed a lower level of activity and fewer cycles during the no-touch contexts compared to the touch contexts. This suggests that the mothers find it more difficult to participate physically when they cannot involve their infants directly. On the other hand, during the mother's favourite music the infants display slightly more actions and cyclical behaviours compared to their own favourite music. So, contrary to our prediction infants are more active during the mother's favourite music although at a slower tempo. Interestingly, Rock and colleagues (1999) also found that infants perform more cyclical behaviours during lullabies compared to playsongs. The authors explained this by the fact that playsongs capture the infant's attention making them stop any ongoing activity. Despite this being possibly true, it is believed that that infants display a more dynamic

participation because of their mothers' reduced activity, so their increased movements might be aimed at prompting their mothers to interact more. However, as expected, physical contact plays a role in the musical interaction. In fact, during the no-touch contexts infants produce a higher level of activity and cyclical behaviours compared to the touch contexts. Infants may be more lively in the absence of physical contact to attract their mothers' into touching and playing with them.

When the musical tempos and the partners' level of activity and cyclical behaviours are considered, it emerges that mothers are more active during the *moderato* and *allegro* tempos, and they produce more cycles with *largo* and *moderato* tempo music. Although during medium to fast tempos a dynamic participation was expected, there turned out to be a rich cyclical activity during the slow tempo. The high cyclical activity during slow tempos is difficult to explain. It could be that during a playful interaction mothers use slow tempos to calm their unsettled infants. On the other hand, infants display a high level of activity during the *adagio* tempo especially and the least with *andante* tempo. Infants are more cyclical during the *allegro* tempo music but they show the least cyclical activity with the *moderato* tempo. Thus it seems that with medium tempo infants produce very little activity in general, as well as less cycles. A more detailed analysis of the kind of cycles mothers perform in musical interaction shows that during the infant's favourite music mothers produce more vertically-oriented cycles with their own head, body, and by toy, e.g., head nodding, body bouncing, hand patting, toy bouncing, compared to the mother's favourite music. Whereas, during the mother's favourite music a higher amount of body cycles and cycles in contact with their infants' body and limbs are used, and these are not only vertical but also horizontal, compared to the infant's favourite music. It could be that during the infant's favourite music, because the musical tempo is faster, it prompts a vertical activity, and to avoid over-stimulating the infants mothers produce cycles with their head, body and toy and some in contact with their infants. But with the mother's favourite music, mothers focus their activity on their infants, perhaps because they want to share their own music with them physically as in a dance. On the other hand, in the no-touch context with the infant's favourite music, infants produce several vertical cycles, i.e., hand bouncing and leg kicking, compared to the mother's favourite music in which they produce mostly horizontal cycles, i.e., hand and leg waving. In the touch contexts, infants display more head nodding and leg cycles with the infant's favourite music compared to the mother's music. Moreover infants perform more hand cycles, in particular hand waving, and head shaking with the mother's

favourite music. Thus it seems that there is a relation between the kind of cyclical patterns and the kind of music.

When we take a closer look at the relation between the partners' kind of cycles and the musical tempos, it emerges that during *largo*, *adagio* and *moderato* tempos mothers produce more cycles touching their infants and in contact with their limbs. On the other hand, during *andante* and *allegro* tempos they produce more cycles with their head and body, and toy, and rarely touch their infants. Thus, during moderate to slow tempos mothers seem to involve their infants directly with several tactile and kinaesthetic stimuli, whereas with faster tempos mothers promote visual and vestibular stimuli which ultimately might be done in order to avoid the over-stimulation of their infants. On the other hand, when the infants' cyclical patterns in relation to the musical tempos are considered, it emerges that infants perform horizontally-oriented cycles across all musical tempos, whereas vertically-oriented cycles, like leg kicking and head nodding, are more frequent with *allegro* and *andante* tempo music. Only rarely infants do move their body in cycles. This is almost in agreement with Trehub (1993) who found that infants of 9-13 months of age produce more vertical cycles, in particular head and body bouncing, during a lively and rhythmical piece of music compared to a melodic one. It could be because the infants in this study are younger, they move their bodies less often. However, it seems that there is a tendency to perform vertical cycles during faster tempos compared to slower ones, not only with respect to the infants but also the mothers.

As far as context is concerned, the mothers display different levels of smiling and touching their infants in relation to the kind of music and the absence or presence of physical contact. First of all, during the infant's favourite music mothers display longer smiling compared to mother's favourite music, in both contexts. Thus, contrary to our prediction, mothers smile more frequently while listening to the infant's favourite music. This could be explained by the fact that the infant's favourite music is especially directed at their infants, similarly to infant-directed songs when mothers also smile longer (Trehub & Zacharias, 1998). On the other hand, the mother's favourite music could be more similar to non-infant-directed songs, i.e., more adult-oriented music, in which mothers smile less often. However, it is interesting to note that in the touch contexts mothers display longer infant touching, and face-to-face contact in the mother's favourite music compared to the infant's favourite music context. Again, in contrast with our expectation, mothers display different communicative-affective behaviours with the two kinds of music. Although they smile less often, during the mother's

favourite music mothers seem to convey care and love through their physical contact perhaps so as to share their feelings and emotions through their own favourite music.

On the other hand, the analysis of the infants' communicative-affective behaviours shows that, as predicted, infants smile for longer and show slightly more active communicative effort during the infant's favourite music compared to the mother's, in both contexts. Thus, it seems that infants recognise their own music, smiling and vocalising. Although in the no-touch context with the infant's favourite music infants touch themselves more often than their mothers, in the touch context they touch their mothers more frequently than themselves. By contrast, during the mother's favourite music infants touch themselves more frequently than their mothers in both contexts. It could be that infants are quite distressed during these contexts and withdraw into themselves. Although it was expected that infants would make more physical contact with their mothers during the infant's favourite music, it seems that during the no-touch context infants are less prone to do so. In fact, they may be used to playing and sharing physically with their own favourite music, so the lack of physical contact might cause infants to become withdrawn. On the other hand, it was expected less physical contact with their mothers during the mother's favourite music because this kind of music is not part of ordinary mother-infant interaction and this might cause infants to be more self oriented. Moreover, as predicted, infants display longer happy states during the infant's favourite music compared to the mother's music. Although during the no-touch context with their own favourite music infants show frequent neutral states, in the same context during the mother's favourite music infants are often even more in a neutral state displaying long very unhappy states. On the other hand, in the touch context with the infant's favourite music they display longer happy and very happy states compared to the same context with their mother's favourite music. Finally, infants' degree of engagement appears to be higher during the infant's favourite music compared to the mother's, in both contexts. Therefore, as predicted, infants are more engaged during their own favourite music compared to their mother's. Thus infants not only seem to recognise their own favourite music but also they enjoy it more and appear more attracted to it compared to the mother's favourite music.

In sum, I hypothesised that infants would show a higher level of activity and cyclical behaviours during their own favourite music compared to their mother's favourite music. It turned out, by contrast, that infants display a higher level of activity and slightly more cyclical behaviours during the mother's favourite music compared to their own. Infants

were expected to produce a smaller amount of behaviours in the no-touch context compared to the touch one, with both types of music. In contrast to my prediction, infants display a higher level of activity as well more cyclical behaviours in the absence of physical contact than in its presence. Therefore, physical contact produces a similar effect on the infant's participation in interaction with both taped music and songs. In fact, infants display a higher level of activity and amount of cyclical behaviours in the absence of physical contact with both kinds of musical interactions (although in interaction with songs, this is only true at 3-4 months). Thus it may be that during musical interactions infants expect some physical activity with their mothers, and if their mothers do not display activity, the infants produce several behaviours perhaps to compensate for the lack of activity in an attempt to prompt their mothers to touch them.

Mothers were expected to display similar or at most slightly more activity and cyclical behaviours during the infant's favourite music compared to their own. In fact, they appear to produce a higher level of activity as well as more cyclical movements during the infant's favourite music compared to their own, thus confirming my hypothesis. Mothers were also expected to produce a similar amount of behaviours irrespective of context. By contrast, they turned out to be affected by physical contact in relation to their level of activity and percentage of cycles. In fact, in the presence of physical contact with their infants, mothers are much more active and cyclical compared to the no-touch contexts. Interestingly mothers display exactly the same pattern during interactions with live songs at 3-4 months and with taped music at 4-5 months. Thus, like their infants, mothers participate similarly during musical interaction with either live songs or taped music in relation to the presence or absence of physical contact. No prediction was made with respect to the partners' level of activity and cyclical behaviours regarding the musical tempo of the taped music. In fact, mothers were found to produce a higher level of activity during *moderato* and *allegro* tempos compared to other tempos. Interestingly, mothers also display the same pattern during interaction with songs. Moreover, mothers turned out to be very cyclical during *moderato* and *largo* tempos during interactions with taped music. Similarly, during interaction with live songs mothers produce a high amount of cycles during *largo* and *allegro* tempos. In contrast, infants display a higher level of activity during slower tempos rather than faster ones. Although infants do not show this pattern during interactions with live songs, they perform the lowest levels of activity during the *andante* tempo with both kinds of musical interaction.

In relation to their amount of cyclical behaviours, infants display very few cycles during the *moderato* tempo in interaction with taped music and only some in interactions with songs. Although with the *moderato* tempo infants do not show the same pattern in the two kinds of musical interaction, with the other tempos they display a similar cyclical participation. If we consider in detail the kinds of cyclical behaviours mothers and infants perform in relation to the musical tempo in interaction with songs and taped music, some similarities but also differences emerge. For instance, with the *largo* tempo mothers perform mostly hand caressing and body rocking during both kinds of musical interactions, but with the same *largo* tempo in interaction with live songs they also perform several head nodding and body bouncing actions. With the *moderato* tempo although mothers produce several bouncing cycles in contact with the baby's limb in both kinds of musical interactions, they do not bounce the baby's body in interactions with taped music. When the infants' cyclical activity is considered in relation to musical tempo during interactions with songs and taped music, more differences than similarities emerge. For instance, compared to interaction with taped music, during interactions with songs infants display a greater variety of cyclical behaviours which also include cyclical activity with a toy. Moreover, in interactions with songs infants produce several leg kicking and waving actions during the *andante* tempo, whereas in interaction with taped music they produce the same cycles mostly with *allegro* and *moderato* tempos. In general, infants appear to perform hand and leg waving, and less so head nodding, with all musical tempos in both kinds of musical interactions. However, it is possible that it is due to the different ages of infants in the live songs versus taped music contexts which explains why they show little relation between musical tempo and kinds of cyclical behaviours. Although mothers' and infants' kinds of cyclical behaviours are not strictly related to the musical tempo of interactions with songs and taped music, it appears that both partners are affected to some extent by musical tempo in their overall level of activity and amount of cyclical behaviours. This suggests that musical tempo plays a relatively important role in mother-infant interaction both when this occurs with live songs or with taped music. In fact, it appears the both partners modify their participation similarly in relation to musical tempo in the presence of songs and taped music.

I hypothesised that infants would show more active CE (i.e., Communicative Effort), smiling, physical contact with their mothers and in general more positive states and degree of engagement during the infant's favourite music compared to the mother's music. Infants do indeed show this pattern, thereby confirming my hypothesis. Infants were expected to show more positive states in the touch contexts compared to the no-touch ones with both types of

music. In line with my prediction, infants display longer positive states in the touch contexts compared to the no-touch contexts with both types of music. Interestingly, it is also the case that in interaction with songs infants display longer positive states in the touch context compared to the no-touch one. Moreover, during the touch context with the infant's favourite music, infants display longer happy and very happy states compared to the mother's music. On the other hand, it was predicted that infants would show very little positive state and degree of engagement as well as the least amount of smiling, vocalisation, and touching the mother, in the no-touch context compared to the touch one with the mother's favourite music. However, a more complex picture emerged. In fact, although infants display longer neutral, very unhappy and shorter positive states during the no-touch context compared to the touch one with the mother's favourite music, they also show longer smiling and higher levels of engagement in the no-touch context compared to the touch one. They show similar amounts of vocalisation and touching the mother in both contexts. This therefore only partially confirms my prediction. Mothers were expected to produce similar amounts of smiling and touching the infant during the touch contexts with both types of music. However, they actually display more touching of the infant with the mother's favourite music, and longer smiling with the infant's favourite music. It was also predicted that mothers would show longer smiling during the no-touch context compared to the touch one with both types of music. In fact, mothers display this pattern with both types of music. Interestingly it also happens that during interactions with songs mothers display longer smiling during the no-touch context compared to the touch one.

Therefore, when the partners' communicative-affective behaviours as well as the infants' emotional states and degree of engagement are considered, it emerges once again that interactions with live songs and taped music share commonalities. In particular, it was shown that in the absence of physical contact during both kinds of musical interactions infants touch themselves for longer periods of time, display longer neutral states and a lower degree of engagement compared to the touch context. On the other hand, during interactions with songs in the touch context, infants display longer smiling, more active CE, touch their mothers more than themselves, display longer happy and very happy states as well as longer periods of a high degree of engagement, compared to the no-touch context. Interestingly, with respect to the infant's favourite music, infants show the same pattern of behaviours only in the touch context. Moreover, the mothers' smiling lasts for much longer in the interaction with the infant's favourite music compared to her own favourite music. These results therefore suggest that the partners' communicative-affective behaviours and the infant's

emotional states and degree of engagement in the interaction with the infant's favourite music share more similarities with the interaction with live songs (especially at 3-4 months of the infant's age).

6.4 Mother and infant synchronisation in interaction with taped music

Synchronisation occurs when response and stimulus occur at the same time (Fraisse, 1982). The anticipation of the stimulus is crucial for matching response and stimulus, and this is facilitated when the sequence of events is periodic. This section explores the phenomenon of synchronisation between onset time events in interaction with taped music with respect to self (section 6.4.1), to the musical beat (section 6.4.2), and to the partner (section 6.4.3).

6.4.1 Mother and infant self synchronisation

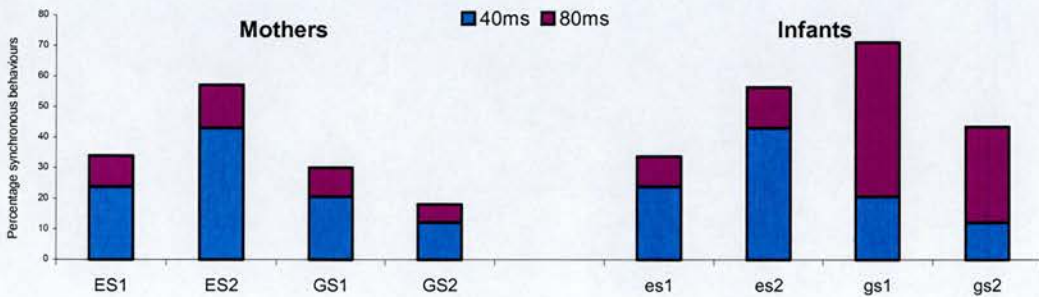
Before proceeding to assess whether mother and infant are able to synchronise with the musical beat and with each other, it is necessary to determine whether they can co-ordinate their behaviours internally. Mothers are claimed to organise their behaviours in self-synchrony. In fact, according to Sullivan and Horowitz (1983), during interaction with their infants mothers co-ordinate tightly their visual, vocal, tactile and kinaesthetic stimuli. However, it is not only mothers who have been found to organise their behaviours in self-synchrony. Even 1-4-day-old neonates have been noted to display self-synchronous behaviours (Condon, 1979), and this occurs even earlier in the womb. For instance, Hepper et al. (1993) observed that foetuses organise their behaviours internally.

What happens during interaction with taped music? Do mother and infant show internal synchrony during interactions with taped music? If so, how accurate are these synchronisations? Does physical contact or the lack thereof affect the infant's self-synchrony? It is predicted that both mother and infant will present internal organisation during taped music interactions. Further, it is hypothesised that physical contact will have an effect on the infant's internal co-ordination and accuracy. In fact, in the touch context, the infant may find it more difficult to match his own behaviours accurately compared to the no-touch context because the mother's activity might interrupt the flow of the infant's behaviours. A major difference in self synchronous behaviours is not expected in relation to the kind of music played, although infants might perform more internally-organised behaviours during the infant's favourite music compared to the mother's favourite music. In order to evaluate these hypotheses, the dataset of taped music interactions presented in

section 6.2.1 was used. This was obtained by asking mothers to play to their 4-5 months-old infants two types of music: their own favourite music and their infants' favourite music, during no-touch and touch contexts. Synchronisation is considered to happen when the onset time behaviours of a partner occur within 40ms (i.e., 0ms to 40ms) and 80ms (i.e., 0ms to 80ms) temporal windows. A detailed explanation of the procedure used to assess self-synchrony is described in Chapter 2, section 2.3.2.1. First of all, the amount of behaviours each partner produces in self-synchrony is measured. This is calculated on the overall amount of behaviours produced by the partner during the interaction. Also the mean and standard error of the distance between the onset times of self-synchronous behaviours are analysed in order to assess the precision of each partner when internally co-ordinating their behaviours.

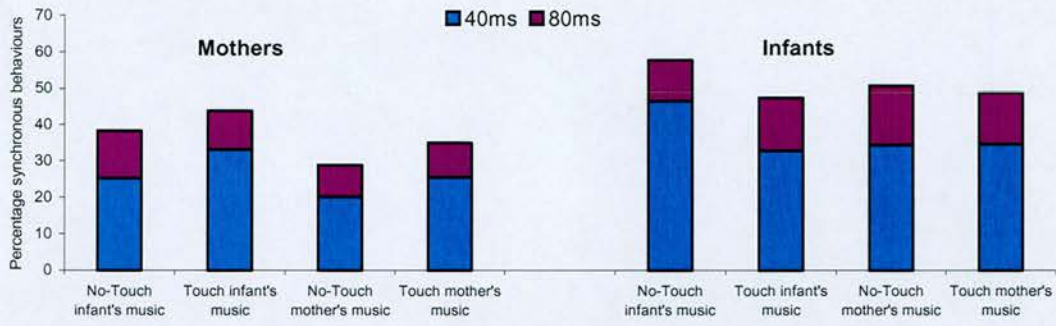
Figures 6.19 and 6.20 show the mothers' and infants' amount of self-synchronous behaviours during interaction with taped music expressed as a percentage of the overall amount of behaviours produced during the interaction. Figures 6.21 and 6.22 display the mean distance, expressed in milliseconds, between the onset times of the partners' behaviours in self-synchrony. In this case the closer the bar is to "0" the more accurate the partner's self-synchronisation.

Figure 6.19 Percentage of mothers' and infants' behaviours that are self-synchronous, as a function of dyad, collapsed across conditions



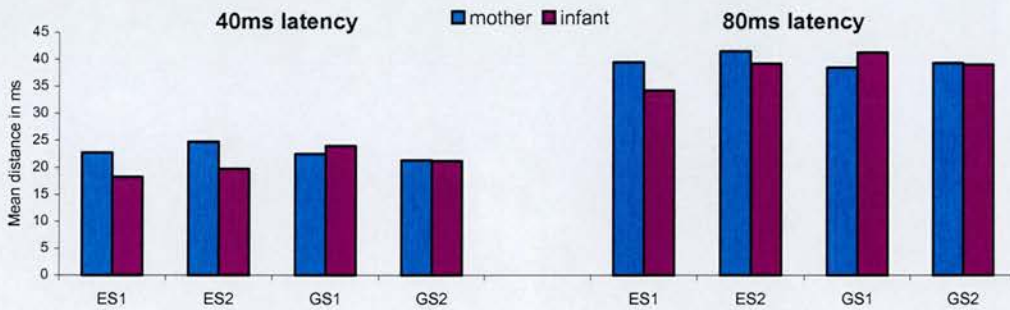
Although on the whole mothers and infants appear to produce the majority of their synchronous behaviours at 40ms latency, see Figure 6.19, the GS infants perform more frequent self-synchronous behaviours at 80ms latency. However, at 40ms latency, both the partners of the ES2 dyad display a higher level of self-synchronous behaviours compared to the other partners, in particular the members of the GS2 dyad who produce the least.

Figure 6.20 Percentage of mothers' and infants' behaviours that are self-synchronous, as a function of condition



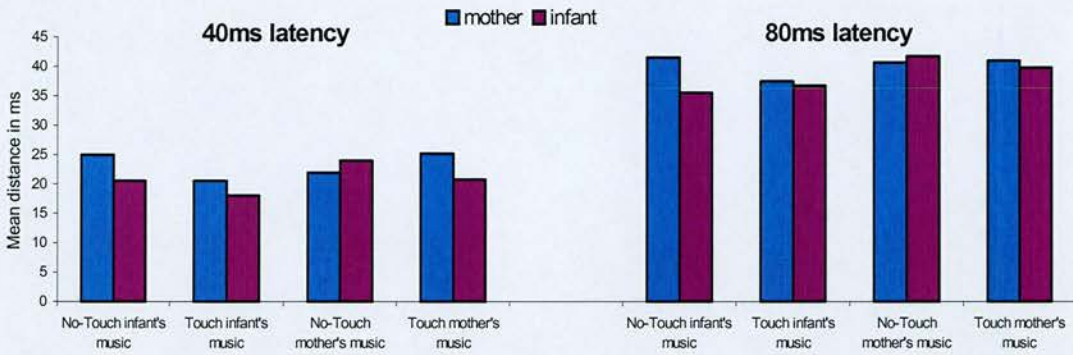
As Figure 6.20 shows, overall mothers appear to produce a higher percentage of self-synchronous behaviours during the infant's favourite music compared to the mother's favourite music. Also, in the touch contexts with both kinds of music, mothers display more self-synchronous behaviours compared to the no-touch contexts. Conversely, infants display frequent self-synchronous behaviours during the no-touch contexts, in particular when they listen to the infant's favourite music.

Figure 6.21 Accuracy of mothers' and infants' self-synchronous behaviours (mean distances between synchronous behaviours), as a function of dyad



As Figure 6.21 shows, overall mothers and infants display a similar mean distance between the onset time behaviours when moving in self-synchrony. However, there are some small differences. For instance, the GS mothers display a slightly more precise organisation of their self-synchronous behaviours compared to the ES mothers, at both latencies. Among the infants, the GS1 infant appears to be somewhat less accurate at internal co-ordination at both latencies compared to the other infants.

Figure 6.22 Accuracy of mothers' and infants' self-synchronous behaviours (mean distances between synchronous behaviours), as a function of condition



As far as conditions are concerned, in Figure 6.22 it emerges that mothers co-ordinate their behaviours more precisely in the touch context during the infant's favourite music but not during the mother's favourite music. On the other hand, during their own favourite music, mothers seem to organise their behaviours slightly better in the absence of physical contact especially at 40ms latency. With respect to infants, they display slightly more accurate self-synchronous behaviours during the touch context with the infant's favourite music compared to the no-touch context. By contrast, infants display little accuracy in internal co-ordination when listening to the mother's favourite music in the no-touch context.

6.4.2 Mother and infant synchronisation with musical beat

This section examines the mother's and infant's synchronisation with the musical beat during interaction with taped music. As mentioned in Chapter 5, section 5.2, people often tap their foot or nod their head to accompany the sequence of sounds when exposed to music. Although it is known that adults synchronise with the regular occurrence of musical stimuli (see Pouthas, 1996) and that the timing of their response depends on the way in which they attend to the musical stimuli (see Jones & Boltz, 1989; Klapp et al., 1985), it is not known whether adults match the musical stimulus during interactions with infants. Moreover, some researchers (see Moog, 1976; Drake et al., 2000) speculated that infants synchronise their behaviours with music, little evidence has been gathered to support this.

Do mothers/infants synchronise with the beat of taped music? If so, do they show the same amount and the same level of accuracy of synchronous behaviours when they synchronise with the musical beat of the infant's favourite music compared to the mother's favourite music? Is the mothers'/infants' synchronisation with the musical beat affected by the

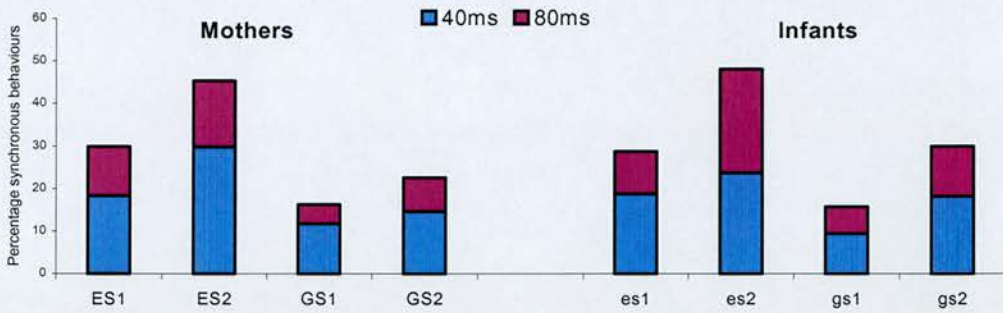
presence or the absence of physical contact? Does musical tempo affect mothers'/infants' synchronisation with the musical beat? Which kind and category of synchronous behaviours do mothers/infants produce during interaction with taped music? Do each of the partners show differences in kind and category of behaviours during the infant's favourite music compared to the mother's favourite music? Do they show similarities between their synchronisation with the beat of live songs compared to taped music?

With respect to the mothers, it is predicted that they will organise their behaviours in synchrony with the music when listening to taped music. Also, it is hypothesised that they will produce a higher amount of synchronous behaviours as well as more accurate synchronisation when listening to their own music compared to the infant's music because they are more familiar with their own music. It is predicted that the presence or absence of physical contact with the infants will not affect mothers' ability to match with the beat. Regarding the tempo of the music, no specific prediction is made with respect to the mothers' synchronisation with the beat. Finally, mothers will show the same kind and category of behaviours during the two kinds of music. With respect to the infants, it is expected that they will also synchronise with the musical beat. In particular, it is hypothesised that they will synchronise more often and more accurately with their own favourite music compared to their mother's favourite music because they are more familiar with the former. In relation to physical contact, infants are expected to show no difference between the no-touch and touch contexts when synchronising with the beat. With respect to the tempo of the music, no specific prediction is made regarding infants' synchronisation. Rather, it is predicted that infants will show synchronous behaviours which are not specific to any kind or category of behaviours. Moreover, no difference in kind and category of synchronous behaviours is expected between the infant's favourite music compared to the mother's music. In order to evaluate these hypotheses was used the dataset of interactions with taped music described in section 6.2.1. Mothers were asked to play two types of music, i.e., the infant's favourite music and the mother's favourite music, to their 4-5 months old infants during no-touch and touch contexts. Synchronisation is considered to occur when the onset times of the partner's behaviours and musical beat are within 40ms (i.e., 0ms to 40ms) and 80ms (i.e., 0ms to 80ms) temporal windows. In Chapter 2, section 2.3.2.2, a detailed explanation of how to assess the partner's behaviours with the musical beat was presented.

Figures 6.23, 6.24 and 6.25 show the amount of the mother's and infant's synchronous behaviours with the beat. Data are expressed as a percentage of the overall amount of

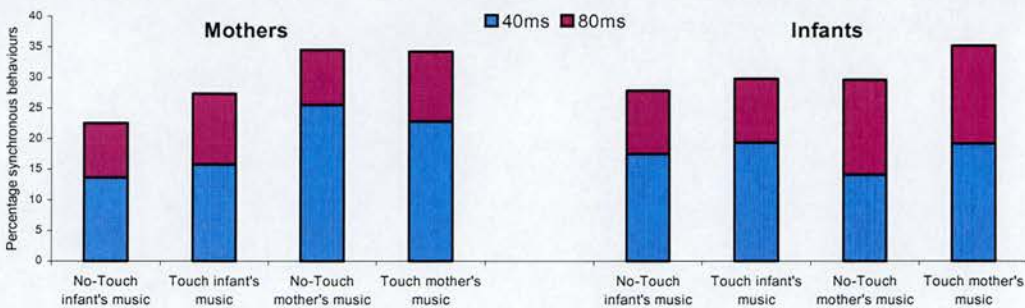
behaviours produced by the partners during the interaction. Figures 6.26, 6.27 and 6.28 illustrate the mean distance between onset time behaviours and musical beats at 40ms and 80ms temporal windows. Data are expressed in milliseconds and the lower the bar the higher the accuracy. Finally, in Figures 6.29, 6.30 and 6.31 the amount of synchronous behaviours is expressed as a function of the region of the beat in which they happen, given as a percentage of the overall amount of synchronous behaviours.

Figure 6.23 Percentage of mothers' and infants' behaviours in synchrony with the beat, as a function of dyad, collapsed across conditions



Although mothers and infants appear to produce more synchronous behaviours with the musical beat at 40ms latency, the ES2 infant displays a higher percentage of synchronous behaviours at 80ms latency than the other infants (see Figure 6.23). The ES mothers, especially the ES2 mother seem to produce more behaviours in synchrony with the beat compared to the GS mothers. Similarly to their mothers, the ES2 infant performs the highest percentage of synchronous behaviours whereas the GS1 infant performs the least.

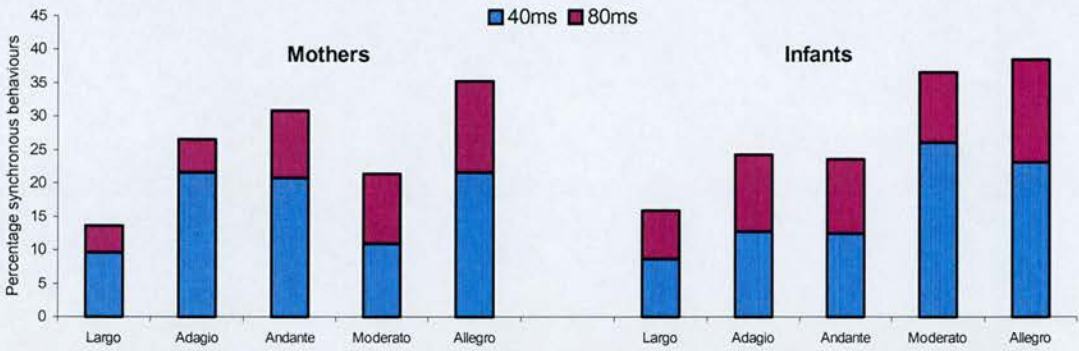
Figure 6.24 Percentage of mothers' and infants' behaviours in synchrony with the beat, as a function of condition



As Figure 6.24 shows, overall both partners produce the majority of their synchronous behaviours with the beat at 40ms latency. However, during the mother's favourite music

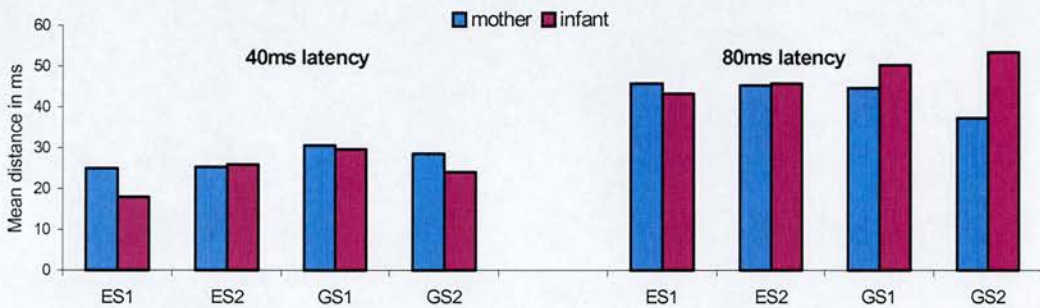
infants display a high percentage of synchronous behaviours with the beat at 80ms latency. Also the mothers perform a higher level of synchronous behaviours with the beat during the mother's favourite music compared to the infant's, at 40ms latency especially. On the other hand, at 40ms latency infants produce more behaviours in synchrony with the beat during the infant's favourite music compared to the mother's music.

Figure 6.25 Percentage of mothers' and infants' behaviours in synchrony with the beat, as a function of musical tempo



It is interesting to observe in Figure 6.25 that although mothers and infants display different percentages of synchronous activity with the beat as a function of musical tempo, they synchronise with the beat more often during the *allegro* tempo and the least with the *largo* tempo. However, mothers also appear to match the beat frequently with the *andante* tempo, whereas for infants it is with the *moderato* tempo.

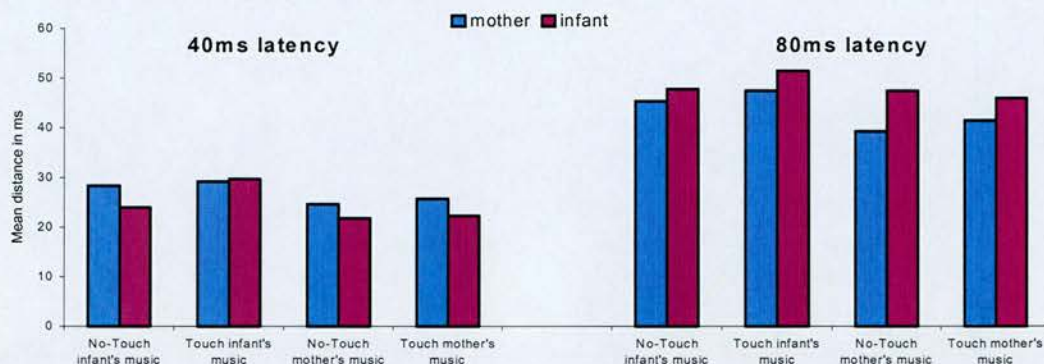
Figure 6.26 Accuracy of mothers' and infants' synchronous behaviours with the beat (mean distances between synchronous behaviours), as a function of dyad



As Figure 6.26 shows, overall mothers and infants display similar accuracy when synchronising with the musical beat. However, there are some differences. For instance, at 40ms latency both partners of the GS1 dyad appear less accurate compared to the others. At

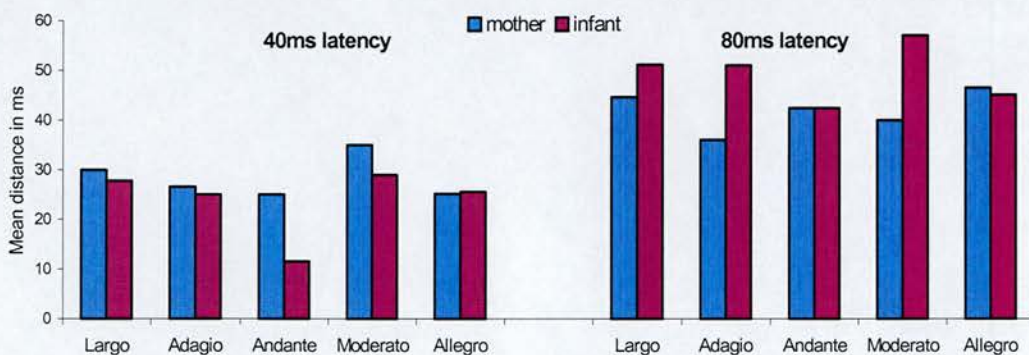
80ms latency, the GS infants display less precision in comparison to the other infants and the mothers.

Figure 6.27 Accuracy of mothers' and infants' synchronous behaviours with the beat (mean distances between synchronous behaviours), as a function of condition



Aside from the touch context with the infant's favourite music, at 40ms latency infants appear more accurate than their mothers when they synchronise with the musical beat (see Figure 6.27). At 80ms latency, by contrast, mothers are more precise than their infants in every context. In general, mothers and infants display higher accuracy with the musical beat during the mother's favourite music compared to the infant's favourite music in both contexts.

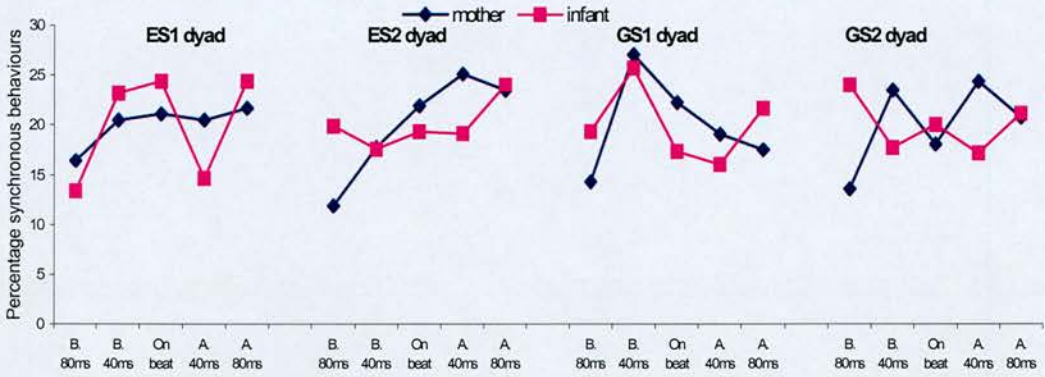
Figure 6.28 Accuracy of mothers' and infants' synchronous behaviours with the beat (mean distances between synchronous behaviours), as a function of musical tempo



As Figure 6.28 shows, when the partners of the dyad synchronise with the beat of taped music they display some variation in relation to musical tempo and latency. For instance, infants show great accuracy during the *andante* tempo especially at 40ms latency. On the other hand, they seem to have more difficulty closely matching the beat at 80ms with *largo*, *andante* and *moderato* tempos. With respect to mothers, they appear to synchronise with the

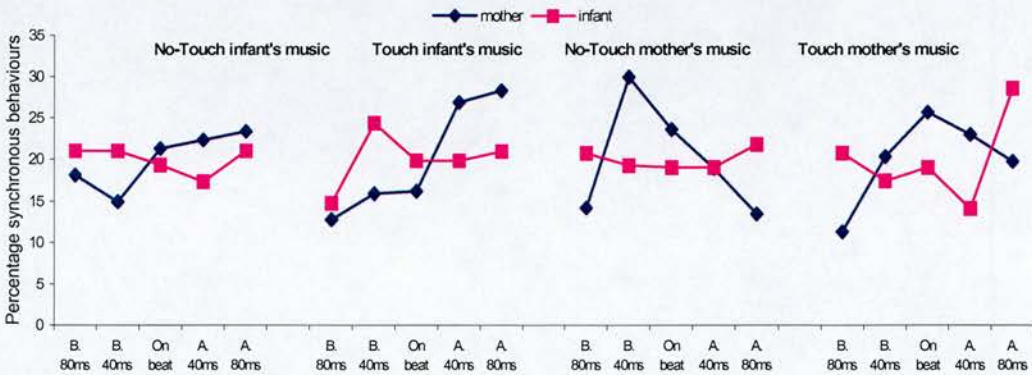
beat similarly across musical tempos at 40ms latency. However, at 40ms latency, they do seem less accurate with the *moderato* tempo. At 80ms latency, they show more precision during the *adagio* tempo compared to the others.

Figure 6.29 Mothers' and infants' percentage of synchronous behaviours before, on and after the beat, as a function of dyad, collapsed across conditions



Mothers and infants display considerable individual variation when matching with the musical beat. However, as Figure 6.29 shows, there are a few similarities among the partners. For instance, both the ES2 partners of the dyad mostly synchronise after the beat, whereas the GS1 dyad synchronise more frequently 40ms before the beat. By contrast, the ES1 and GS2 dyads show a less neat picture synchronising both before as well as on and after the beat.

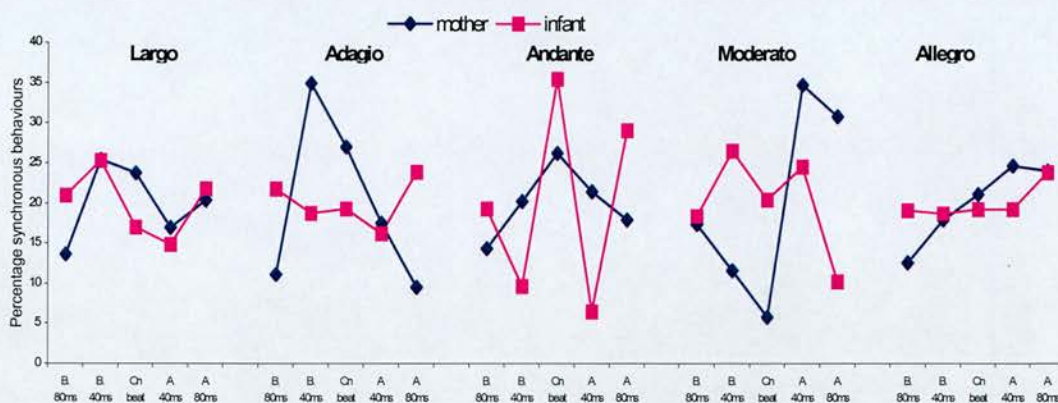
Figure 6.30 Mothers' and infants' percentage of synchronous behaviours before, on and after the beat, as a function of condition



As Figure 6.30 shows, the mothers' and infants' percentage of behaviours in synchrony with the musical beat seems somewhat related to context and type of music. For instance, during the infant's favourite music mothers seem to synchronise more often 80ms after the beat. By

contrast, with the mother's favourite music mothers appear to organise their behaviours more accurately matching either 40ms before the beat in the no-touch context, or exactly on the beat in the touch context. Similarly, infants seem to display a more accurate synchronisation with the beat during their own favourite music compared to the mother's. In fact, during the infant's favourite music infants match often 80/40ms before the beat, whereas with the mother's favourite music they synchronise more often 80ms after the beat.

Figure 6.31 Mothers' and infants' percentage of synchronous behaviours before, on and after the beat, as a function of musical tempo



When musical tempo is considered, mothers and infants display variations in relation to the region of the beat on which they synchronise. However, with *largo*, *andante* and *allegro* tempos both mothers and infants match respectively 40ms before, exactly on the beat, and 80ms after the beat. By contrast with *adagio* and *moderato* tempos, the partners of the dyad display different patterns of synchronisation with the beat.

6.4.2.1 The partners' synchrony with the musical beat

In order to assess whether mothers and infants synchronise significantly with the musical beat of the taped music, Chi square tests were applied. The procedure is the same as applied in the assessment of significant synchronisation with the musical beat for live songs, and explained in Chapter 5, section 5.2.2. In the present section, Chi square tests have been applied to the synchronisation with the musical beat as a function of dyad, condition, and musical tempo, at 40ms, i.e., 120ms, and 80ms, i.e., 200ms, temporal windows. Similarly to section 5.2, in the following section I will use the shorthand forms 40ms and 80ms latencies for convenience sake.

Table 6.4 Chi-square analyses of the infants' behaviours in synchrony with the musical beat as a function of infant, collapsed across conditions

	Infant	Observed moves In synchrony	Observed moves Not in synchrony	Expected moves In synchrony	Expected moves Not in synchrony	Number beat	Tot beat duration	χ^2	p value
40ms latency									
	ES1	51	236	62.34	224.66	419	248.76	2.64	ns
	ES2	308	983	342.23	948.77	703	318.86	4.66	.030*
	GS1	181	1812	194	1799	262	323.01	.96	ns
	GS2	106	594	106.18	593.82	391	303.06	.000	ns
80ms latency									
	ES1	82	205	103.90	183.09	419	248.76	7.23	.007*
	ES2	546	745	570.39	720.61	703	318.86	1.87	ns
	GS1	304	1689	323.34	1669.66	262	323.01	1.38	ns
	GS2	176	524	176.97	523.03	391	303.06	.00	ns

As Table 6.4 shows, none of the infants synchronise significantly with the beat at either of the temporal windows. However, at 40ms latency the ES2 infant and at 80ms latency the ES1 infant shows significantly less behaviours in synchrony with the beat than would be expected.

Table 6.5 Chi-square analyses of the mothers' behaviours in synchrony with the musical beat as a function of mother, collapsed across conditions

	Mother	Observed moves In synchrony	Observed moves Not in synchrony	Expected moves In synchrony	Expected moves Not in synchrony	Number beat	Tot beat duration	χ^2	p value
40ms latency									
	ES1	111	495	131.76	474.24	419	248.76	4.18	.040*
	ES2	363	808	308.29	862.71	703	318.86	13.18	.000
	GS1	42	255	35.47	261.53	262	323.01	1.37	ns
	GS2	72	445	89.92	427.08	391	303.06	4.32	.037*
80ms latency									
	ES1	181	425	219.61	386.39	419	248.76	10.64	.001*
	ES2	559	614	514.66	658.34	703	318.86	6.81	.009
	GS1	62	235	59.11	237.89	262	323.01	.17	ns
	GS2	111	406	149.87	367.13	391	303.06	14.19	.000*

Only the ES2 mother synchronises significantly with the beat at both temporal windows. The GS1 mother instead does not show any significant effect. On the other hand, the ES1 and GS2 mothers produce, at both latencies, significantly less behaviours in synchrony with the beat than expected.

Table 6.6 Chi-square analyses of the partners' behaviours in synchrony with the musical beat, as function of condition (40ms latency)

Condition	Observed moves In synchrony	Observed moves Not in synchrony	Expected moves In synchrony	Expected moves Not in synchrony	Number beat	Tot beat duration	χ^2	p value
Infant								
No-Touch infant's music	170	1146	195.43	1120.57	343	250.02	3.88	.048*
Touch infant's music	113	460	116.97	456.03	505	304.64	.17	ns
No-Touch mother's music	229	1321	254.06	1295.93	442	316.79	2.96	ns
Touch mother's music	134	698	138.30	693.70	485	322.24	.16	ns
Mother								
No-Touch infant's music	52	258	78.12	231.87	343	250.02	11.68	.000*
Touch infant's music	211	868	242.40	836.60	505	304.64	5.25	.020*
No-Touch mother's music	90	252	72.30	269.69	442	316.79	5.49	.019
Touch mother's music	235	625	172.61	687.39	485	322.24	28.21	.000

At 40ms latency, infants do not synchronise significantly with the beat either in relation to the kind of music or in the presence or absence of physical contact. However, in the no-touch context with the infant's favourite music, infants show significant effect in the opposite direction. On the other hand, the mothers' significant synchronisation with the musical beat appears to be related to the kind of music rather than the context. In fact, mothers synchronise significantly during the mother's favourite music. During the infant's favourite music by contrast, mothers produce significantly less behaviours than expected.

Table 6.7 Chi-square analyses of the partners' behaviours in synchrony with the musical beat, as function of condition (80ms latency)

Condition	Observed moves In synchrony	Observed moves Not in synchrony	Expected moves In synchrony	Expected moves Not in synchrony	Number beat	Tot beat duration	χ^2	p value
Infant								
No-Touch infant's music	294	1022	325.71	990.28	343	250.02	4.10	.042*
Touch infant's music	176	397	194.95	378.05	505	304.64	2.79	ns
No-Touch mother's music	406	1144	423.44	1126.56	442	316.79	.99	ns
Touch mother's music	232	600	230.50	601.50	485	322.24	.013	ns
Mother								
No-Touch infant's music	93	219	131.05	180.95	343	250.02	19.05	.000*
Touch infant's music	356	723	404	675	505	304.64	9.12	.002*
No-Touch mother's music	125	217	120.51	221.49	442	316.79	.26	ns
Touch mother's music	339	521	287.68	572.32	485	322.24	13.76	.000

At 80ms latency, infants display a pattern similar to the 40ms latency one. Thus they do not synchronise significantly with the beat in any of the conditions. In particular, during the no-touch context with the infant's favourite music they move significantly less than expected. The mothers synchronise significantly with the beat only in the touch context with the mother's music. Again, they show a significant effect of synchrony with the beat in the opposite direction during the infant's favourite music in both contexts.

Table 6.8 Chi-square analyses of the partners' behaviours in synchrony with the musical beat, as function of musical tempo (40ms latency)

Condition	Observed moves In synchrony	Observed moves Not in synchrony	Expected moves In synchrony	Expected moves Not in synchrony	Number beat	Tot beat duration	χ^2	p value
Infant								
Largo	145	1600	147.45	1597.55	300	384.07	.04	ns
Adagio	107	707	122.58	691.42	202	161.48	2.33	ns
Andante	16	111	22.25	104.75	235	160.80	2.13	ns
Moderato	35	99	30.15	103.84	151	80.52	1	ns
Allegro	343	1108	382.33	1068.67	887	406.82	5.49	.02*
Mother								
Largo	38	301	35.41	303.59	300	384.07	.21	ns
Adagio	49	179	34.39	193.61	202	161.48	7.30	.007
Andante	56	213	47.17	221.82	235	160.80	2	ns
Moderato	27	220	55.58	191.41	151	80.52	18.97	.000*
Allegro	418	1090	392.88	1115.12	887	406.82	2.17	ns

When 40ms temporal window is considered infants appear not to be able to synchronise significantly with any of the taped music tempos. However, with *allegro* tempo infants produce significantly less behaviours in synchrony with the beat than would be expected. On the other hand, the mothers synchronise significantly with the beat only during *adagio* tempo, whereas with *moderato* tempo there is a significant effect in the opposite direction.

Table 6.9 Chi-square analyses of the partners' behaviours in synchrony with the musical beat, as function of musical tempo (80ms latency)

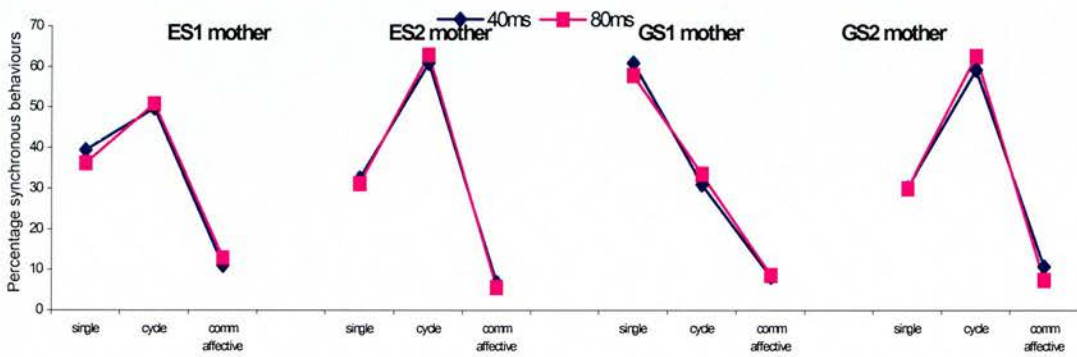
Condition	Observed moves In synchrony	Observed moves Not in synchrony	Expected moves In synchrony	Expected moves Not in synchrony	Number beat	Tot beat duration	χ^2	p value
Infant								
Largo	232	1513	245.75	1499.25	300	384.07	.89	ns
Adagio	199	615	204.29	609.71	202	161.48	.18	ns
Andante	31	96	37.08	89.92	235	160.80	1.41	ns
Moderato	49	85	50.26	83.74	151	80.52	.05	ns
Allegro	597	854	637.21	813.79	887	406.82	4.52	.03*
Mother								
Largo	58	281	59.02	279.98	300	384.07	.02	ns
Adagio	62	166	57.32	170.68	202	161.48	.51	ns
Andante	83	186	78.63	190.37	235	160.80	.34	ns
Moderato	53	194	92.64	154.36	151	80.52	27.14	.000*
Allegro	657	853	524.51	985.49	887	406.82	51.28	.000

With a larger temporal window for synchrony, infants show exactly the same pattern as for the smaller one, i.e., no significant effect of synchrony except for *allegro* tempo where the significant effect is in the opposite direction than predicted. Interestingly *allegro* is the only tempo at which the mothers synchronise significantly, whereas with *moderato* tempo they produce significantly less synchronous behaviours than expected.

6.4.2.2 The partners' kind and category of behaviours in synchrony with the musical beat

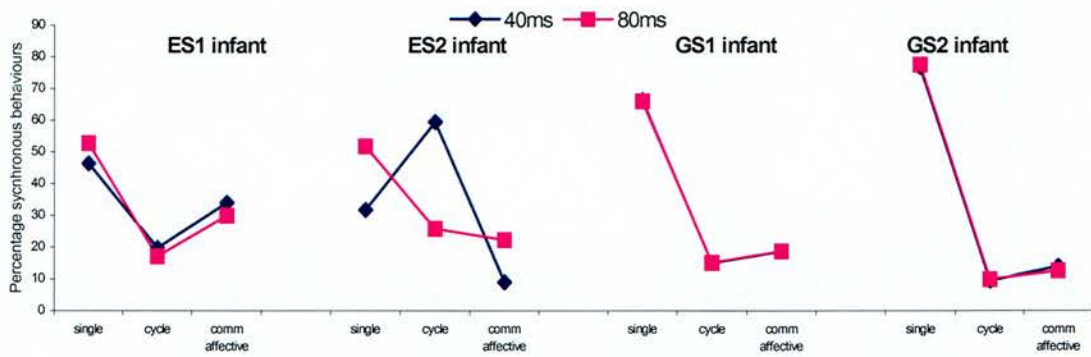
This section examines the kind and category of synchronous behaviours with the beat performed by mothers and infants during interaction with taped music. In particular, Figures 6.26 and 6.27 show the mothers' and infants' kinds of synchronous behaviours with the beat, which include: single gestures, cyclical actions and communicative-affective behaviours. Figures 6.28 to 6.30 display the most common cyclical behaviours mothers and infants perform when they match with the musical beat. Finally, Figures 6.31 and 6.32 present the mothers' and infants' category of behaviours in synchrony with the beat in interaction with taped music. In particular the mothers' category of synchronous behaviours include: head/body, hand/leg, touch baby, and toy, whereas the infants' category include: head/body, hand, leg, and touch mother. In every figure, data are expressed as a percentage of the overall amount of synchronous behaviours with the beat.

Figure 6.32 Percentage of mothers' kinds of behaviours in synchrony with beat as a function of mother, collapsed across conditions



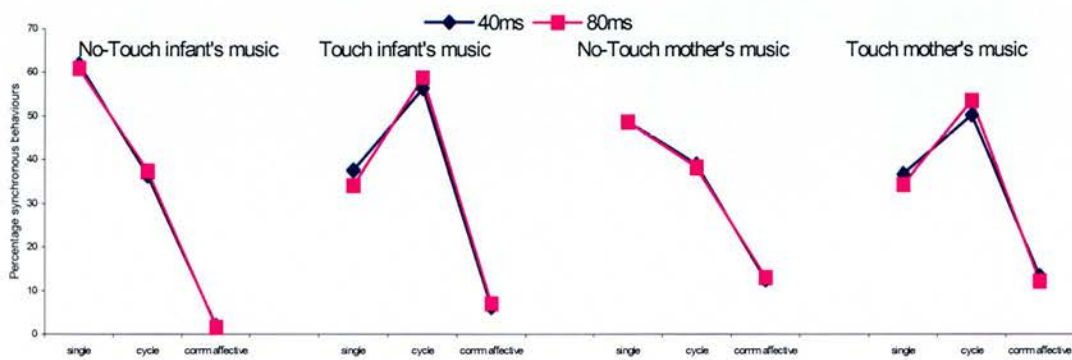
Overall the mothers produce mostly cyclical behaviours in synchrony with the musical beat and less often single gestures. Only the GS1 mother matches more single gestures in synchrony with the beat compared to cyclical actions. Mothers rarely use communicative-affective behaviours to match the beat. There is no effect of latency on these results.

Figure 6.33 Percentage of mothers' kinds of behaviours in synchrony with beat as a function of infant, collapsed across conditions



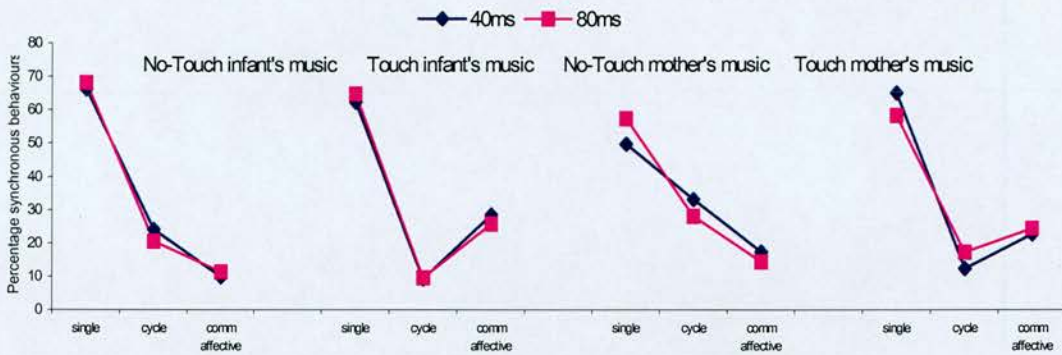
Aside from the ES2 infant who produces mostly cyclical behaviours at 40ms latency, all the other infants match the musical beat more frequently with single gestures. Again, apart from the ES2 infant, results are similar for both latencies.

Figure 6.34 Percentage of mothers' kinds of behaviours in synchrony with beat, as a function of condition



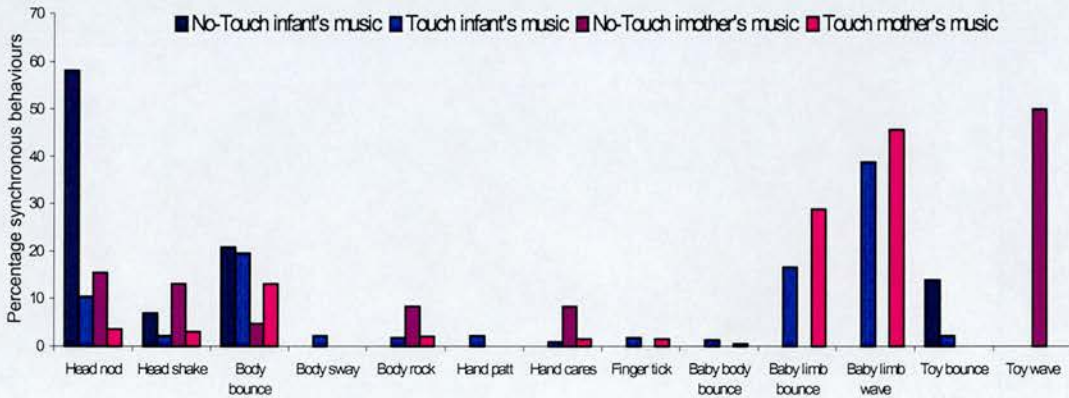
In both no-touch contexts mothers perform mostly single gestures in synchrony with the musical beat. On the other hand, during the touch contexts mothers produce more cyclical behaviours in synchrony with beat. Interestingly, during both contexts with the mother's favourite music mothers perform slightly more communicative-affective behaviours in synchrony with the beat compared to the infant's favourite music.

Figure 6.35 Percentage of infants' kinds of behaviours in synchrony with beat, as a function of condition



Overall infants appear to synchronise more often with the musical beat through single gestures in all conditions. However, it is interesting to observe that during the no-touch contexts infants also perform many cyclical behaviours in synchrony with the beat. In the touch contexts, by contrast, infants more frequently produce communicative-affective behaviours to match the beat. In general, during the mother's favourite music, infants appear to produce more cycles in synchrony with the beat compared to the infant's favourite music.

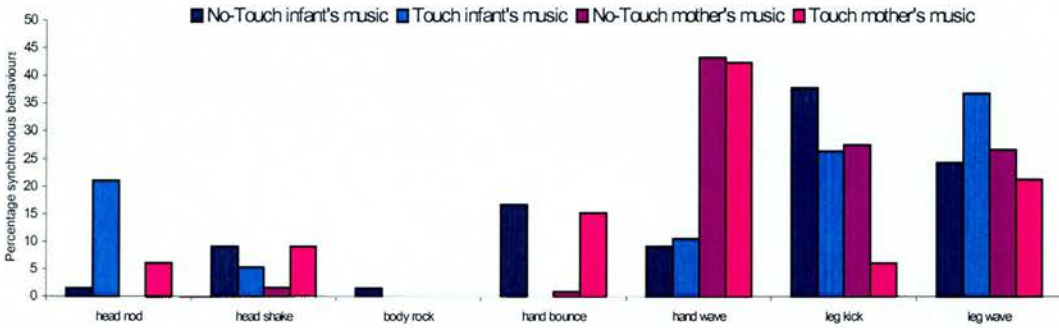
Figure 6.36 Percentage of mothers' type of cyclical patterns in synchrony with the beat, as a function of condition



For mothers, first of all, it is interesting to note that in any of the contexts and during both types of music mothers synchronise with the beat through head nodding and shaking, as well as body bouncing. However, there are some cycles that appear to occur more often with one kind of music rather than the other. In fact, during the infant's favourite music mothers produce mostly vertical cycles, whereas with the mother's favourite music they perform mostly horizontal cycles. Moreover, in the no-touch context with the mother's favourite music, mothers match the beat also through body rocking, hand caressing and toy waving,

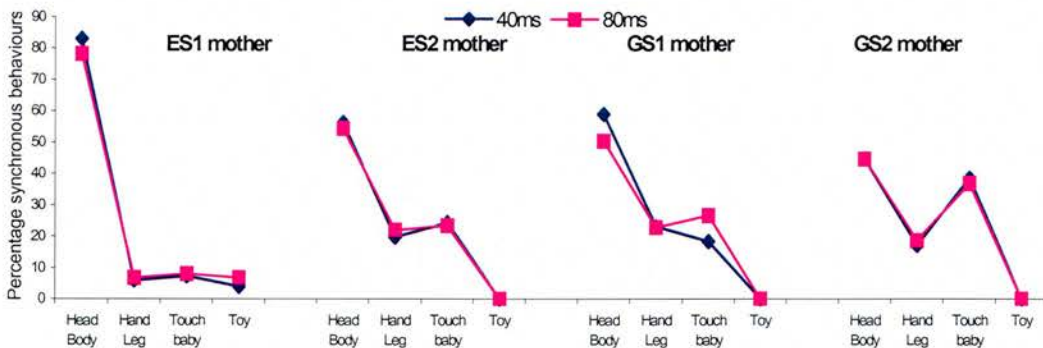
whereas during the infant's favourite music they tend to bounce the toy. In the touch contexts, although mothers produce cycles in contact with their baby's limbs, they appear to do so more often with the mother's favourite music compared to the infant's.

Figure 6.37 Percentage of infants' type of cyclical patterns in synchrony with the beat, as a function of condition



As Figure 6.37 shows, infants synchronise with the beat through hand waving and leg cycles in all conditions. However, they show some differences in relation to the kind of music. For instance, during the mother's favourite music in both contexts infants produce a high percentage of hand waving. On the other hand, infants appear to produce more leg cycles and head nodding during the infant's favourite music compared to the mother's. Finally, infants seem to produce cycles which are neither related to context nor to the type of music. In fact, they display hand bouncing both during the infant's favourite music in the no-touch context as well as in the touch-context with the mother's favourite music.

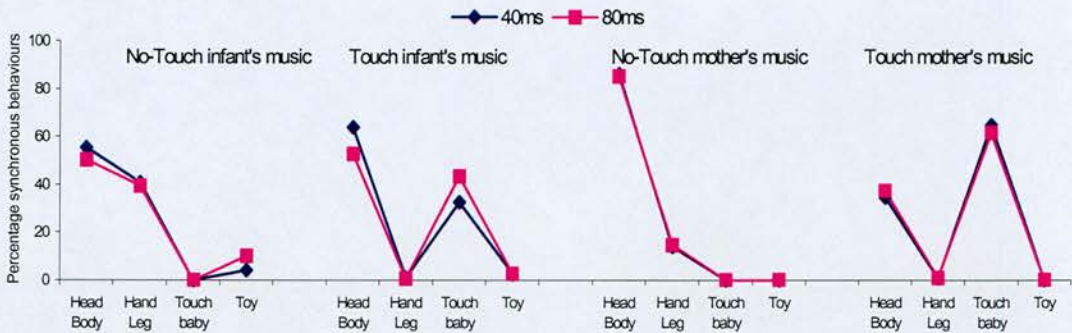
Figure 6.38 Mothers' percentage of category of behaviours in synchrony with the beat, as a function of mother, collapsed across conditions



Overall mothers use firstly head and body behaviours, and secondly behaviours in contact with their infants in order to match the musical beat (see Figure 6.38). The GS2 mother

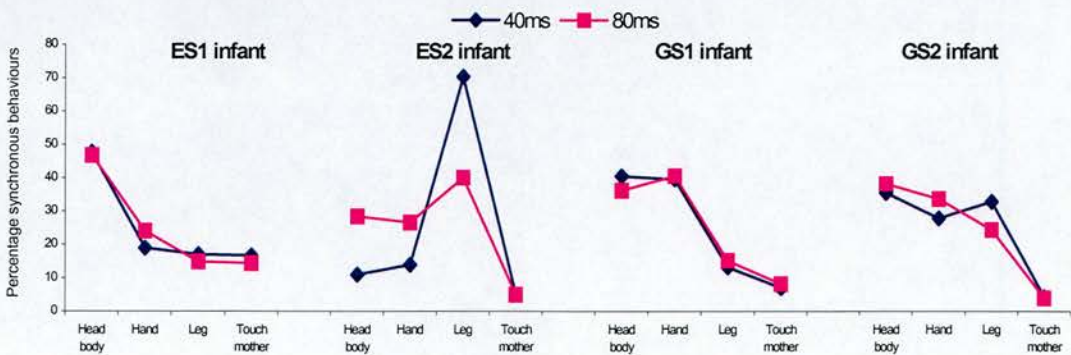
appears to touch her infant more frequently compared to the others. By contrast, the ES1 mother rarely touches her infant in synchrony with the beat; instead, she displays toy activity with the beat.

Figure 6.39 Mothers' percentage of category of behaviours in synchrony with the beat, as a function of condition



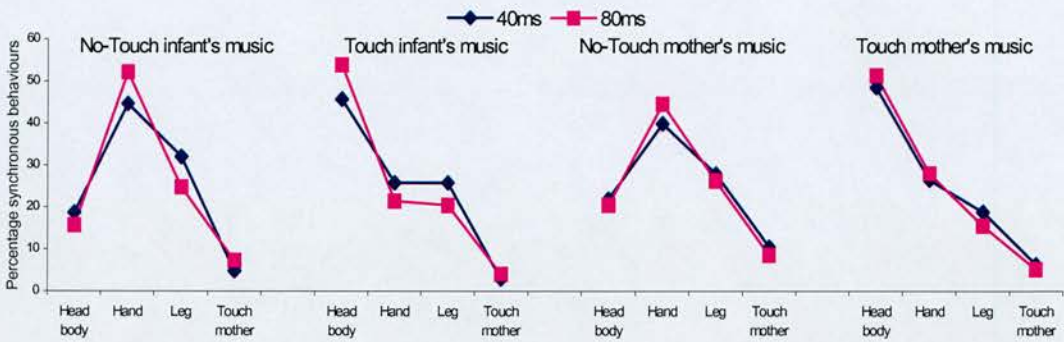
Overall mothers synchronise more often with the musical beat through their head and body. However, as shown in Figure 6.39, some differences arise in the other categories of behaviours related to the kind of music and the presence or absence of physical contact. For instance, in the no-touch contexts mothers also match the beat more frequently with hand and leg behaviours during infant's favourite music compared to the mother's favourite music. Moreover, during the infant's favourite music mothers use also a toy which they do not use during the mother's favourite music. In addition, in the touch contexts mothers perform more synchronous behaviours in contact with their infants during the mother's favourite music compared to the infant's favourite music.

Figure 6.40 Infants' percentage of category of behaviours in synchrony with the beat, as a function of infant collapsed across conditions



As Figure 6.40 shows, infants display considerable individual differences regarding the category of behaviours they use to synchronise with the beat. For instance, the ES2 infant performs mostly leg behaviours in synchrony with the beat, whereas the ES1 infant uses head and body actions. The GS infants, by contrast, both use more than one category in synchrony with the beat. Thus, the GS1 infant produces head, body and hand behaviours in matching the beat. Finally, aside from rarely touching the mother in synchrony with the musical beat, the GS2 infant performs all the categories similarly.

Figure 6.41 Infants' percentage of category of behaviours in synchrony with the beat, as a function of condition



In Figure 6.41 it emerges that infants display different categories of synchronous behaviours according to the presence or absence of physical contact with their mothers. During the no-touch contexts, infants synchronise with the beat primarily with their hand behaviours, and do so even more often during the infant's favourite music than during the mother's favourite music. During the touch contexts, by contrast, infants synchronise with the beat mostly through their head and body gestures, and secondarily with their limbs. However, during the infant's favourite music infants synchronise with the beat to a similar percentage through their hand and leg behaviours, whereas during the mother's favourite music they use their hand more often than leg.

6.4.3 Mothers' and infants' synchronisation with each other

So far the phenomenon of synchronisation has been explored in relation to the partners' internal co-ordination and their ability to organise their behaviours with respect to an auditory stimulus. However, synchronisation is also an important phenomenon of the interaction itself, implying the ability of the partners to anticipate and match with each other's behaviours. 'Interactional synchrony' consists in the ability of each partner to co-ordinate his behaviours in synchrony with the phrases and words of the speaker (Condon,

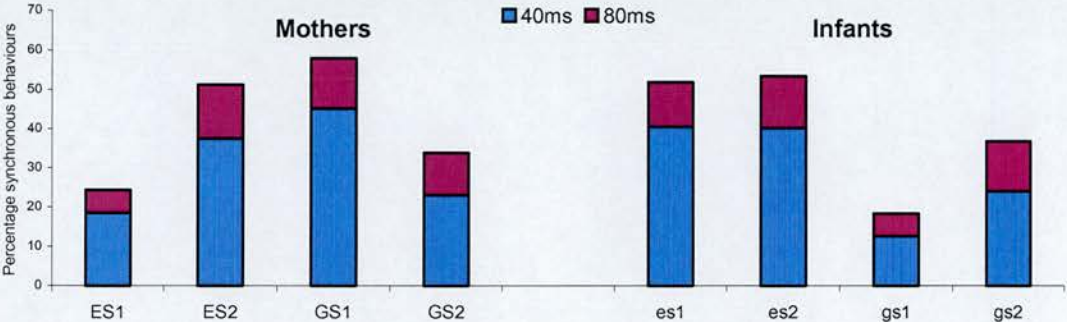
1979). Synchronisation between partners of an interaction does not occur only between adults, but also occurs, as Condon and Sander (1974) demonstrated, when newborns are one of the partners of the interaction. Indeed, the phenomenon of synchronous and harmonious interaction has been studied by several researchers (for example Beebe et al., 1982; Brazelton et al., 1974; Papousek, 1996) because of its implications for a healthy and qualitatively positive interaction. Although synchronisation between mother and infant is considered important for the quality and flow of the interaction, this phenomenon has not hitherto been explored in interaction with taped music. Do mother and infant synchronise with each other's behaviours during musical interaction with taped music? If so, how accurate are they in their synchronisation? Do they show different amounts of behaviour and levels accuracy during the infant's favourite music compared to the mother's favourite music? Does physical contact affect their ability to synchronise with each other? How many behaviours will the mother or the infant synchronise with one another? Which kind and category of synchronous behaviours will the partners of the dyad show the most?

During taped music, it is predicted that mothers and infants will synchronise with each other's behaviours. It is expected that mothers will show a higher percentage of behaviours in synchrony with their infants' behaviours during the infant's music compared to their own favourite music, in order to give special emphasis to the infant's music. No difference in accuracy between the two kinds of music is predicted. However, it is hypothesised that during the no-touch context mother and infant will have more difficulty in matching each others' behaviours compared to the touch-context. No difference in the category of behaviours the mothers produce in synchrony with the infant during the two kinds of music is expected. However, it is predicted that mothers' cyclical activity will increase during the infant's favourite music compared to their own favourite music. It is anticipated that the infants also will produce more actions in synchrony with their mothers during their own favourite music compared to the mother's music. In addition, it is predicted that the infants will produce more often cyclical actions of the limbs when listening to their own music compared to the mother's music.

In order to evaluate these hypotheses, the dataset of interaction with taped music presented in section 6.2.1 was used. This was achieved by asking the mothers to play their own favourite music and their infants' favourite music to their 4-5 months old infants during no-touch and touch contexts. The mother's and infant's synchronous behaviours are assessed when their onset time behaviours occur within 40ms (i.e., 0ms to 40ms) and 80ms (i.e., 0ms to 80ms)

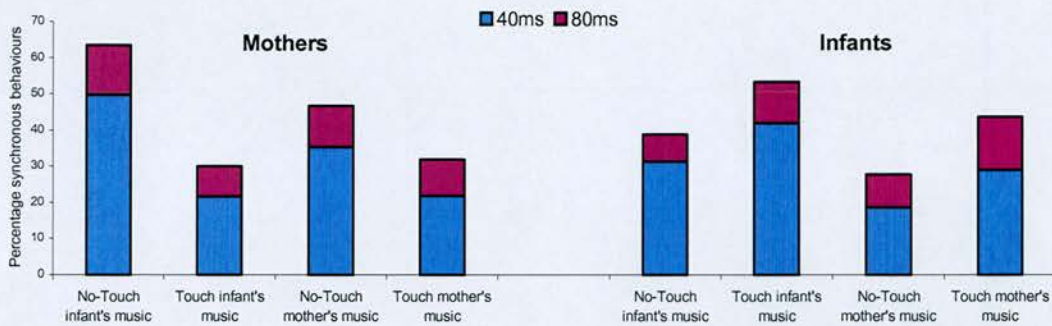
temporal windows. The explanation of the procedure used to measure mother and infant synchronisation in musical interaction was presented in Chapter 2, section 2.3.2.3. Figures 6.42 to 6.44 below show the overall amount of the mothers' and infants' synchronous behaviours with each other expressed as a percentage of the overall amount of behaviours performed by each partner during the interaction. Figures 6.45 to 6.47 display the accuracy of the partners of the dyad when they match each other's behaviours in interaction with taped music. The mean distance between the onset times of the partners' synchronous behaviours is expressed in milliseconds and the closer to "0" the more accurate the partners are. Figures 6.48 to 6.51 display the mothers' and infants' kinds of synchronous behaviours with each other which include: single, cyclical and communicative-affective behaviours. Data are expressed as a percentage of the overall amount of synchronous behaviours. Finally, the category of synchronous behaviours produced by mothers and infants when matching each other's activity is shown in Figures 6.52 to 6.55. The category of the mother's synchronous behaviours include: head/body, hand/leg, in contact with baby, and toy. The category of the infant's synchronous behaviours include: head/body, hand, leg, in contact with mother, and toy. Data are expressed as a percentage of the overall amount of synchronous behaviours.

Figure 6.42 Percentage of mothers' and infants' behaviours in synchrony with each other as a function of dyad, collapsed across conditions



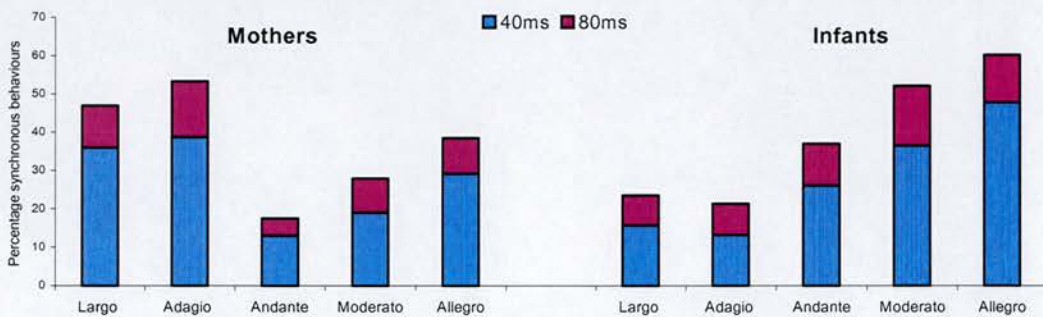
As shown in Figure 6.42, it appears that all the partners of the dyads produce a larger percentage of synchronous behaviours at 40ms latency rather than 80ms latency. However, it is interesting to observe that the ES1 and GS1 partners of the dyad are complementary to each other, i.e., one partner produce lots of synchronous behaviours whereas the other one only a small amount. On the other hand, the partners of the ES2 and GS2 dyads produce a similar amount of synchronous behaviours, i.e., both partners perform either a few or several behaviours in synchrony with each other.

Figure 6.43 Percentage of mothers' and infants' behaviours in synchrony with each other as a function of condition



As far as conditions are concerned, in Figure 6.43 it emerges that mothers and infants produce opposite amount of synchronous behaviours. For instance, during the no-touch contexts mothers produce a larger amount of synchronous behaviours compared to the touch contexts. By contrast, infants produce more synchronous behaviours in the touch contexts than in the no-touch ones. Moreover, during the infant's favourite music infants perform a larger amount of synchronous behaviours with their mothers compared to the mother's music. Finally, during the no-touch contexts the mothers synchronise more frequently with their infants for the infant's favourite music than for their own favourite music, whereas during the touch contexts, they show a similar percentage of synchronous behaviours for both types of music.

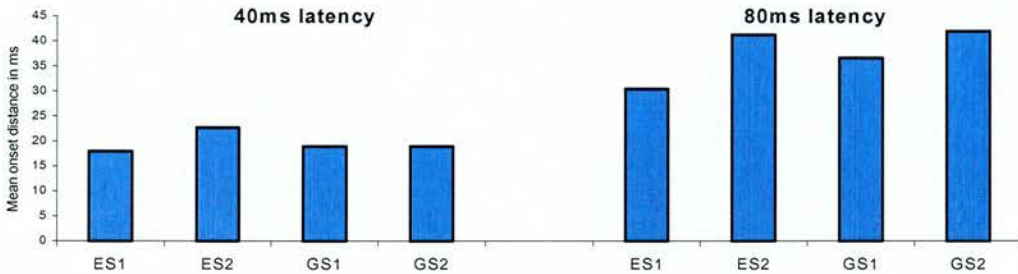
Figure 6.44 Percentage of mothers' and infants' behaviours in synchrony with each other, as a function of musical tempo



When the musical tempo of the taped music is considered, it is interesting to note that during slow tempos the partners of the dyad compensate to allow for each other's synchronous participation. In particular, mothers match more frequently their infants' behaviours during slow tempos compared to medium to fast tempos in which mothers synchronise less often with their infants. By contrast, infants match the least of behaviours with their mothers

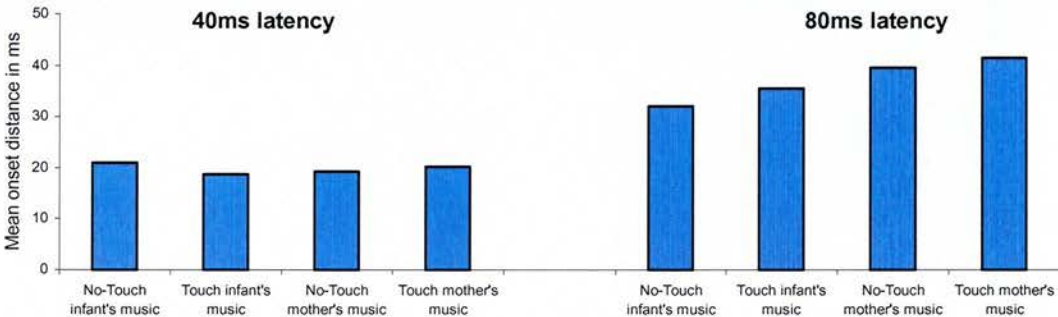
during the slow tempo music whereas during medium to fast tempos, i.e., *andante*, *moderato* and *allegro*, infants synchronise more frequently with their mothers' behaviours.

Figure 6.45 Accuracy of mothers' and infants' synchronous behaviours with each other (mean distances between synchronous behaviours), as a function of dyad, collapsed across conditions



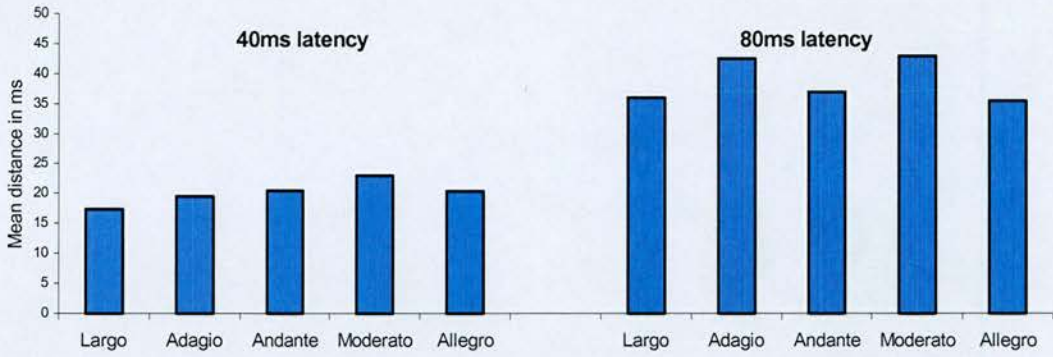
As Figure 6.45 shows, at 40ms latency, the dyads are similarly close when synchronising with each other. At the 80ms latency the partners of the ES1 dyad match their behaviours quite accurately. By contrast, the ES2 and GS2 dyads synchronise less precisely with each other.

Figure 6.46 Accuracy of mothers' and infants' synchronous behaviours with each other (mean distances between synchronous behaviours), as a function of condition



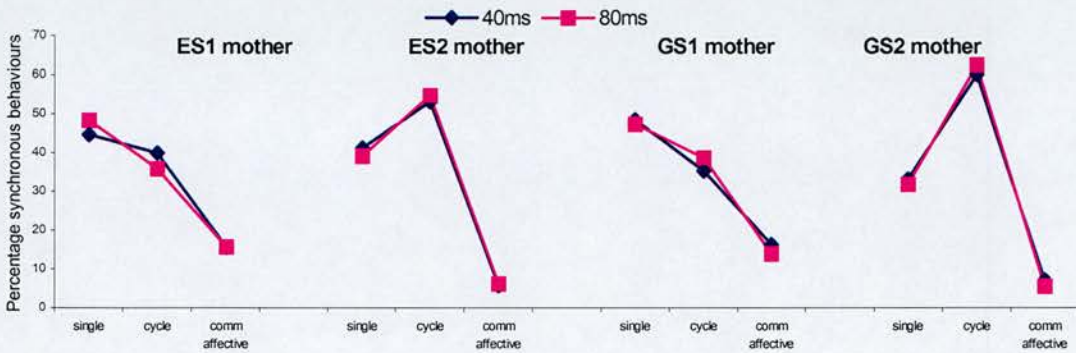
At 40ms latency the partners of the dyad match each other behaviours at a similar mean onset distance in every taped music context. However, at 80ms latency mothers and infants synchronise with each other's behaviours more accurately during the infant's favourite music, especially in the no-touch context, compared to the mother's favourite music.

Figure 6.47 Accuracy of mothers' and infants' synchronous behaviours with each other (mean distances between synchronous behaviours), as a function of musical tempo



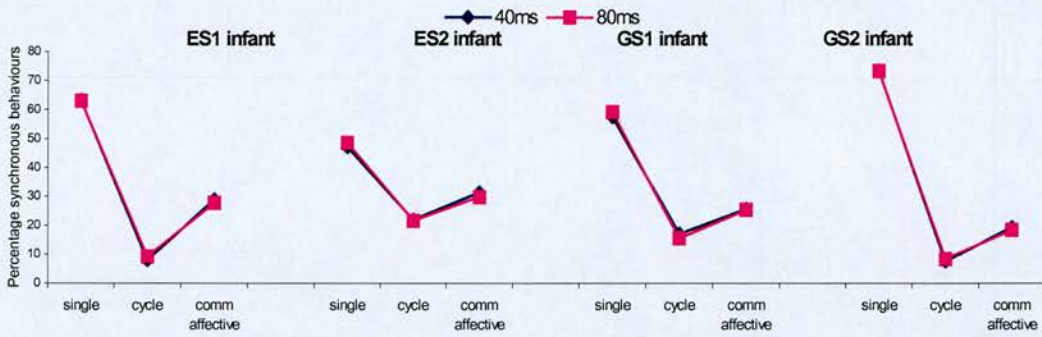
As Figure 6.47 shows, when the partners of the dyad synchronise with each other as a function of musical tempo, they display similar accuracy at 40ms latency, whereas at 80ms latency they show some differences. In fact, it emerges that during the *largo*, *andante* and *allegro* tempos, mothers and infants are more precise in matching each other's behaviours compared to the other tempos.

Figure 6.48 Mothers' kind of behaviours in synchrony with their infants as a function of mother, collapsed across conditions



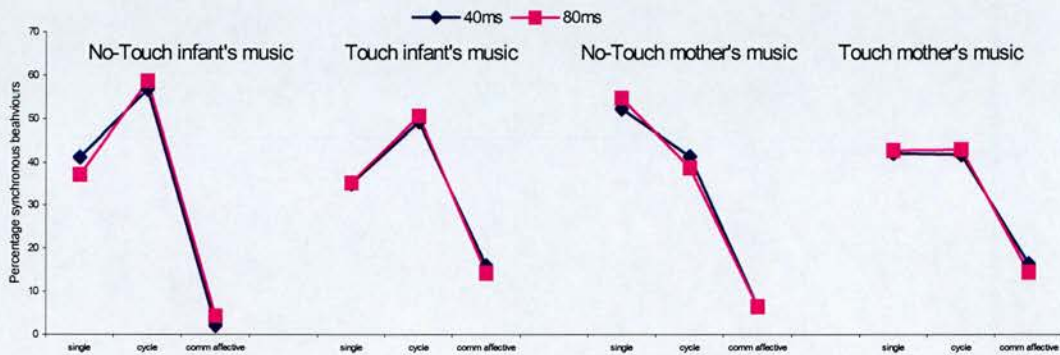
As Figure 6.48 shows, across conditions mothers appear divided in the kinds of behaviours they perform in synchrony with their infants. In fact, the ES2 and GS2 mothers appear to produce mostly cyclical behaviours, whereas the ES1 and GS1 mothers use single gestures to match with their infants'. No difference emerges regarding latency.

Figure 6.49 Infants' kind of behaviours in synchrony with their mothers as a function of infant, collapsed across conditions



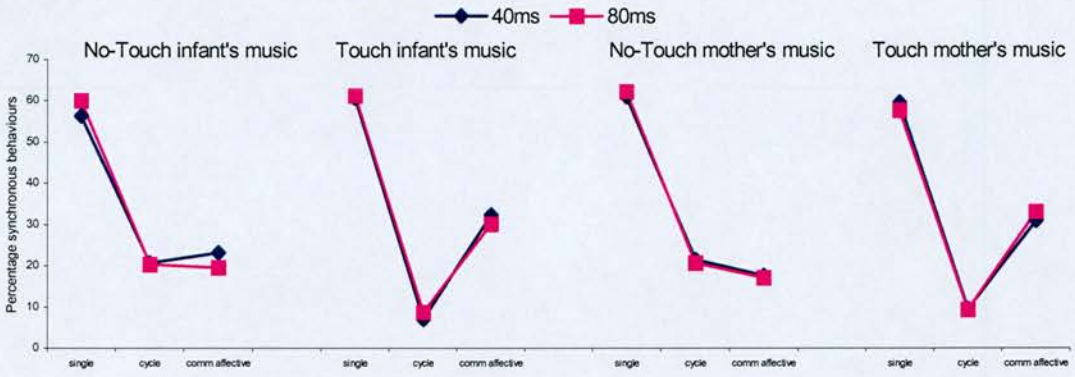
In Figure 6.49, infants display a more uniform pattern of synchronous behaviours compared to their mothers. In fact, infants match their mothers' behaviours through single gestures principally and secondarily by communicative-affective behaviours. Again results are similar at both latencies.

Figure 6.50 Mothers' kind of behaviours in synchrony with their infants, as a function of condition



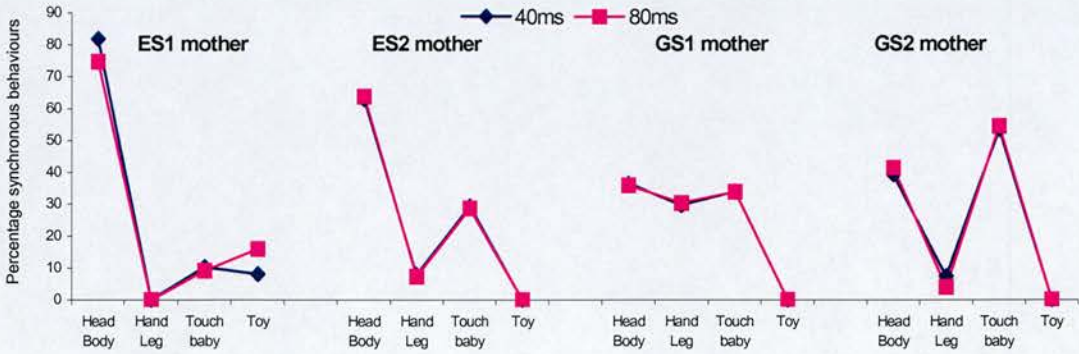
As Figure 6.50 shows, the kind of behaviours mothers produce in synchrony with their infants' differ according to the type of music. In fact, during the infant's favourite music mothers are more likely to match with their infants' actions through their cyclical behaviours. By contrast, during the mother's favourite music mothers synchronise with their infants' behaviours through single gestures in the no-touch context, and either by single gesture or cyclical actions in the touch context. Finally, in the touch contexts with both kinds of music, mothers display a slightly higher percentage of communicative-affective behaviours in synchrony with their infants compared to the no-touch contexts.

Figure 6.51 Infants' kind of behaviours in synchrony with their mothers, as a function of condition



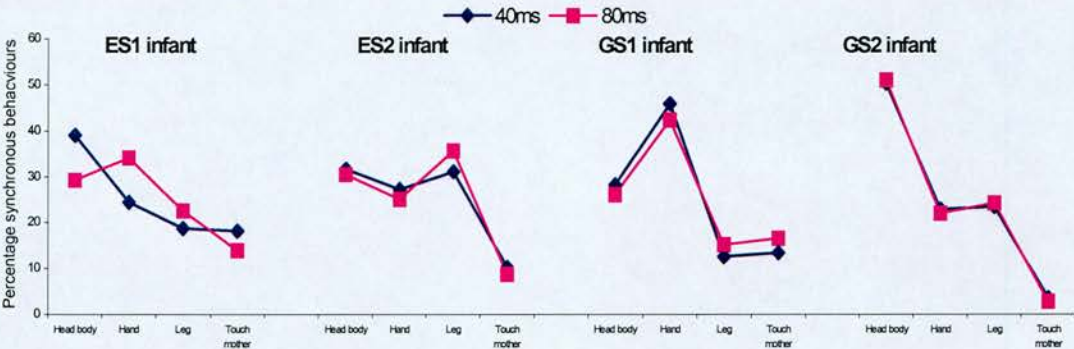
Overall infants appear to match with their mothers' participation principally through their single gestures. In fact, they show this pattern across each condition. However, during the no-touch contexts infants also synchronise with their mothers through either cyclical or communicative-affective behaviours, whilst in the touch contexts they perform mainly communicative-affective behaviours in synchrony with their mothers' activity. They show no difference in relation to kind of music or latency.

Figure 6.52 Mothers' category of behaviours in synchrony with their infants, as a function of mother, collapsed across conditions



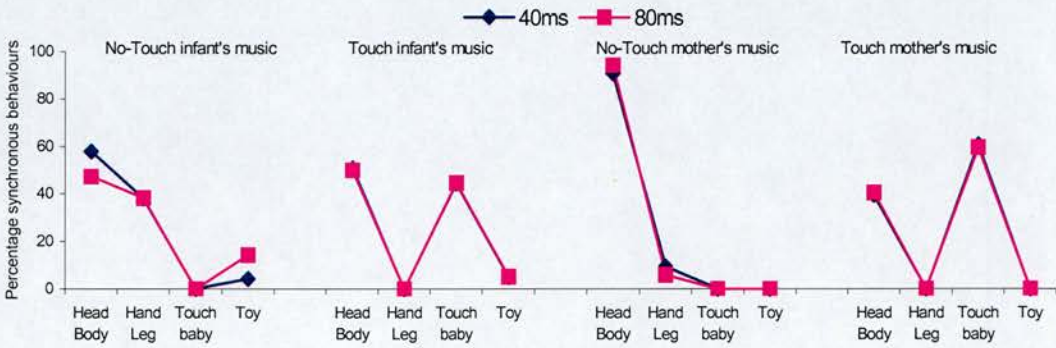
In Figure 6.52 it is interesting to note how mothers differ from one another when synchronising with their infants in interaction with taped music. For instance, the ES1 mother produces mostly head and body behaviours in synchrony with her infant, whereas the GS2 mother mainly touches her infant to match with him. The ES2 mother seems to be half-way between these mothers. In fact, she matches her infant through head and body behaviours as well as touching her. Finally, the GS1 mother performs behaviours with different parts of her body, limbs and in contact with her infant to match with her.

Figure 6.53 Infants' category of behaviours in synchrony with their mothers, as a function of infant, collapsed across conditions



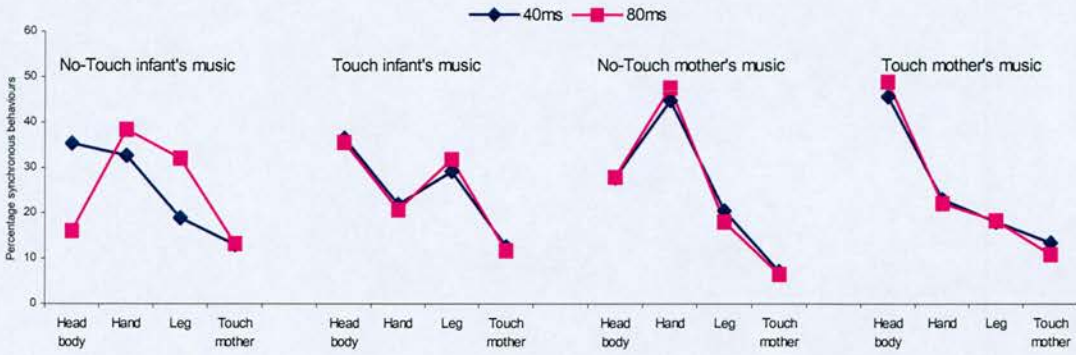
Infants display even more individual variation than their mothers regarding the category of behaviours they produce in synchrony with their mothers. In fact, the ES2 infant matches her mother mostly through leg behaviours, the GS1 infant through hand behaviours and the GS2 infant with head and body actions. Also the ES1 infant displays mostly head and body behaviours in synchrony with his mother at 40ms latency, whereas at 80ms latency he matches mostly through hand gestures.

Figure 6.54 Mothers' category of behaviours in synchrony with their infants, as a function of condition



As Figure 6.54 shows in synchronising with their infants mothers perform different categories of behaviours according to the presence or absence of physical contact mostly. During the no-touch context with the infant's favourite music mothers use a variety of behaviours to match their infants' participation which involve their head, body and limbs, as well as with the toy. By contrast, with the mother's favourite music mothers' synchronous behaviours are focused on their head and body, and only occasionally their limbs. In both touch contexts, mothers match with their infants through their head, body, and touching their infants.

Figure 6.55 Infants' category of behaviours in synchrony with their mothers, as a function of condition



Overall, from Figure 6.55 it emerges that infants produce a larger variety of category of behaviours to synchronise with their mothers while listening to their own favourite music compared to the mother's music. For instance, during the no-touch context with the infant's favourite music infants match with their mothers through head, body and hand behaviours at 40ms latency, and hand and leg behaviours at 80ms latency. By contrast, in the same context but with the mother's favourite music infants move mostly their hands in synchrony with their mothers. In the touch context with the infant's favourite music head, body and leg behaviours are often performed by infants in synchrony with the mothers. On the other hand, in the same context but with the mother's favourite music infants match their mothers' behaviours mostly with their head and body.

6.4.4 Discussion and conclusions regarding mothers' and infants' synchronisation with self, the musical beat and the other partner

As predicted, mothers and infants organise internally their behaviours in interaction with taped music. Although most of the partners produce the majority of their self-synchronous behaviours at 40ms latency, the GS infants do not. It could be that they found it more difficult to organise their activity internally during taped music interaction. On the other hand, infants display a higher level of self-synchronous behaviours in the no-touch context with their own favourite music compared to the touch context. Although I predicted more precise internal activity of the infants in the no-touch contexts, in fact they display less accuracy in the absence of physical contact, especially during the mother's favourite music context. By contrast, infants display slightly better accuracy during the touch context with the infant's favourite music. Thus familiarity of the music seems to facilitate the production of infants' internally co-ordinated behaviours perhaps. On the other hand, in interactions

with songs, infants show higher and more precise self-synchronous behaviours in the absence of physical contact. Thus infants organise their behaviours differently in interactions with songs versus taped music and as a function of the absence or presence of physical contact. Overall mothers display a higher level of self-synchronous behaviours during the infant's favourite music especially in the touch context, compared to their own music. This might be due to the fact that mothers are more accustomed to moving together in interaction with their infants when they use their infant's 'special' music. On the other hand, mothers show little accuracy and less self synchronous behaviours not only in the absence of physical contact, but also during their own favourite music. In this case mothers might not be used to sharing their own music with the infants and thus they have more difficulty in co-ordinating their own activity. Also in interactions with songs, mothers display better accuracy and more self-synchrony in the touch context suggesting that physical contact facilitates the mothers' internal co-ordination. Therefore, as Sullivan and Horowitz (1983) suggested, during interaction with infants mothers co-ordinate their vocal, tactile and kinaesthetic stimuli. It was shown that they do so more frequently when the interaction is directly related to their infants, i.e., with the infant's favourite music, compared to when the interaction is less directly related to their infants, i.e., with the mother's favourite music.

With respect to the musical beat of taped music only the ES2 mother displays significant synchronisation with the beat at both latencies, whereas in interaction with songs only the GS1 mother synchronises significantly with the beat at both latencies. On the other hand, none of the infants synchronise significantly with the beat of taped music. This suggests that the mechanical occurrence of the musical beat in taped music does not facilitate the partners, especially the infants, in anticipating the beat accurately and organising their behaviours accordingly. Interestingly, during interaction with both songs and taped music, a relation emerges between the amount of synchronous behaviours with the beat performed by each partner within the same dyad. Hence, if one partner synchronises often with the beat, so does the other partner. Although it is difficult to know whether it is the infant affecting the mother or vice versa, we may speculate that if the mother experiences difficulties in matching with the beat, so her infant may have the same problems. On the other hand, if the infant moves independently of the beat, the mother may fail to follow the beat of the music in order to attune with him.

With respect to conditions, as predicted, mothers produce a higher and more accurate amount of synchronous behaviours with the beat during the mother's favourite music compared to

the infant's music. This holds in both contexts. In fact, during their own favourite music mothers match often 40ms before the beat, i.e., in the no-touch context, and exactly on the beat, i.e., in the touch context. Thus mothers are probably more familiar with the temporal organisation of their own favourite music which allows them not only to synchronise more accurately with the beat but also to produce a higher amount of synchronous behaviours with the beat compared to the infant's music. By contrast, during the infant's favourite music the mothers not only match less often the beat compared to their own favourite music, but they are also less accurate, matching mostly 80ms after the beat. Interestingly, Chi square analysis shows that the mothers synchronise significantly with the beat of the mother's favourite music in both contexts at 40ms latency, and at 80ms only in the touch context. This suggests that during musical interaction with their infants familiarity with the music, i.e., the mother's own favourite music, allows mothers to synchronise significantly with the beat. On the other hand, in the absence of physical contact and with the infant's favourite music, mothers are more concentrated on their infants than on the music. Similarly to interaction with songs, mothers tend to match mostly 80ms after the beat and fail to synchronise with the beat during the no-touch context with infants at 3-4 months of age. These results suggest first of all that interaction with the infant's favourite taped music at 4-5 months of age shares some similarities with interaction with live songs at 3-4 months. Secondly, in both kinds of musical interaction, mothers appear to be more concerned about their infants' state because of the lack of physical contact than the type of music. In fact, during the infant's favourite music, mothers are probably much more accustomed to touching and playing with their infants. Thus, in contrast with our prediction, physical contact turns out to play an important role in the mother's synchronisation with the musical beat.

With respect to infants, Chi square analysis shows that they do not match significantly the beat in any of the conditions at both latencies. Moreover, infants perform significantly less synchronous behaviours with the beat than would be expected during the no-touch context with the infant's favourite music. Therefore, when infants are exposed to taped music, similarly to live songs, they display a significant effect in the opposite direction which could be explained by the fact that they regularly miss the beat. Or it could be that they systematically produce their behaviours away from the beat or even between beats. Interestingly, infants are overall more accurate with the musical beat of the mother's favourite music than their own at both latencies. However, after a closer look at the region where infants synchronise more often with the beat, it emerges that although they do not show large differences in the no-touch contexts, they do in the touch contexts. In fact, during

the infant's favourite music infants match often 40ms before the beat whereas with the mother's favourite music they frequently match 80ms after the beat. Thus similarly to the case of the mothers, the familiarity of the musical piece is, as predicted, also important for the infants if they are to succeed in matching the beat closely. However, in contrast to their mothers, infants need physical contact in order to show more accuracy in their synchronisation with the beat to their own favourite music, thus in contrast with my prediction. Also in the interaction with songs, infants synchronised accurately with the beat in the touch context compared to the no-touch one, although only at 40ms latency. It is probable that infants can focus better on the musical temporal structure when it is totally integrated into the interaction. In fact, it is impossible to say whether infants match with the beat only on the basis of the auditory input because, of course, they are also surrounded by their mothers' actions which are temporally co-ordinated and involve different modalities. Moreover, as seen in Chapters 3 and 5, mothers organise their singing and synchronous behaviours to match exactly on the same beats, thus enabling infants to perceive and integrate information from different several modalities. This integration may help the infants to build a representation of the musical interaction and to organise and co-ordinate their behaviours accordingly.

When the musical tempo of the taped music is considered, mothers and infants appear to be prompted to produce a higher level of synchronous behaviours with faster music, but fewer actions with slower tempo music. Thus with the *allegro* tempo, both partners of the dyad synchronise very often, whilst with the *largo* tempo they do so only occasionally. Similarly to interactions with songs, mothers and infants synchronise more often with the musical beat of faster tempo songs rather than slower ones. Synchronisation with the musical beat of taped music shows that mothers synchronise significantly with the beat in different ways as a function of tempo, whereas infants do not show any significant effect in relation to musical tempo. As far as taped music is concerned, mothers show significant synchronisation with *adagio*, at 40ms, and *allegro*, at 80ms, musical tempos. The infants, by contrast, only show a significant effect in the opposite direction than predicted during *allegro* tempo at both latencies. With respect to live songs, the pattern is somewhat similar, but it also reveals some differences. With live songs mothers show significant synchronisation for *allegro* only at 40ms whereas for taped music their synchronisation at *allegro* is significant at 80ms. For *moderato*, mothers are proficient at 80ms latency for live songs, but not for taped music. The *adagio* tempo is significant only at 40ms latency and with taped music. Infants display poorer results for the live songs as well as the taped music compared to their mothers.

Indeed, infants fail to show significant synchronisation at all tempos for both live songs and taped music. On the other hand, the mothers are unable to match significantly the beat of both songs and taped music at *andante* tempo. This is perhaps because medium tempo is perceived as neither too slow nor too fast and they thus serve to set the pace of the interaction in such a way that the partners become more focused on the interaction with each other rather than on the music. By contrast, infants display better accuracy with both songs and music at the *andante* tempo, suggesting that although they do not match it significantly, they show a tendency to move along with it. On the other hand, faster tempos not only prompt a richer synchronous activity but also the mothers show a significant level of synchronisation whereas the infants synchronise significantly only in the opposite direction. Thus, although no prediction was made regarding the mothers' and the infants' synchronisation with the beat in relation to musical tempo, and Chi square analysis show only few significant results for the mothers and some significant results in the opposite direction for the infants, it emerges that both partners are somewhat affected by variations in tempo when matching the beat of both taped music and songs.

When consideration is given to the kinds of synchronous behaviours produced by the partners to match the beat, it emerges that overall some mothers, i.e., the ES2 and GS2 mothers, produce mostly synchronous cyclical behaviours, and the others, i.e., the ES1 and GS1 mothers, produce synchronous single and cyclical behaviours. Interestingly, these mothers show the same patterns of synchronisation with the beat in interaction with both songs and taped music. This indicates that the way the mothers match the beat is quite robust, i.e., either single gestures, cyclical actions, or both, irrespective of kind of musical interaction. On the other hand, although infants synchronise with the beat especially through single gestures, they also appear to be affected by the kind of musical interaction, i.e., song versus taped music. For instance, the GS2 infant matches more often with the beat through cyclical behaviours during interactions with songs compared to taped music. By contrast, the ES2 infant synchronises more often through cycles in interaction with taped music rather than songs. With respect to conditions, mothers match with the beat through single gestures in the no-touch contexts, and cyclical actions in the touch contexts. It could be that in the absence of physical contact, they are too focused on their infants to be able to organise their cyclical behaviours in synchrony with the beat. Interestingly, also in interaction with songs, the mothers appear to match the beat through single gestures especially in the absence of physical contact. It could be that from the mother's point of view, music is less part of the interaction in the no-touch context. On the other hand, when the mothers' kind of

synchronous cycles with the beat is explored, it appears that in the no-touch contexts during the infant's favourite music mothers produce more synchronous, vertically-oriented cycles compared to the mother's favourite music. Moreover, in the touch contexts, mothers produce a wider variety of cyclical patterns during the infant's favourite music compared to the mother's favourite music. In the latter case, they tend to focus more on cycles in contact with the infant. This indicates that during the infant's favourite music mothers use a variety of temporally co-ordinated modalities, i.e., visual, tactile, vestibular, kinaesthetic, to convey the temporal structure of the music. However, during the mother's favourite music, although they perform different kinds of cycles, mothers appear to focus on activity in direct contact with their infants. It is possible that because infants are less familiar with the mother's taped music, mothers intend to convey the temporal structure directly through rhythmical activity in contact with their infant's limbs. On the other hand, in interaction with songs, mothers seem to modify their synchronous cyclical participation in relation to context and especially to the infant's age. Therefore, overall the mothers' kinds of synchronous behaviours with the beat does not appear affected by the type of music whereas their kinds of cyclical behaviours are affected by the type of music. This partially confirms my prediction that the mothers would show the same kinds and categories of synchronous behaviours with the beat with the two types of music.

With respect to infants, they match the beat through single gestures in every condition during interactions with both songs and taped music. Infants seem to produce more vertically-oriented, synchronous cycles during the infant's favourite music, compared to the mother's music in which they perform more horizontally-oriented, synchronous cycles. This is partially in contrast with my hypothesis that infants would show no difference in kind of synchronous behaviours between the types of music. Although the infants' different orientation of cycles occurs only during the no-touch contexts, it is still an interesting phenomenon, which may be related to the tempo of the music. However, infants show great differences in synchronous cyclical behaviours with the beat in interaction with taped music versus interaction with songs. This could be due to the fact that infants are prompted to move differently in different conditions or it could be due to the fact that they are at different points of development, younger when tested with songs, and almost a couple of months older when tested with taped music. Future research would, of course, need to avoid confounding age with type of music in order to answer this question.

With respect to the mothers' category of synchronous behaviours with the beat, it emerges that they use mostly head and body in both kinds of musical interactions, i.e., both songs and taped music. However, in the touch contexts of interaction with songs, mothers produce also some synchronous behaviours in contact with their infants. These represent about 30% of synchronous behaviours. By contrast, in interaction with taped music, mothers produce several behaviours in contact with their infants in synchrony with the beat, especially during the mother's favourite music. In fact, in this context mothers produce about 60% of their synchronous activity with the beat in contact with the infant, more in fact than their synchronous activity with their head and body. This turns out to be in contrast with the prediction that mothers would produce the same category of synchronous behaviours with both type of music. Perhaps mothers try to convey to their infants the temporal structure of the music with which they are less familiar because it is the mother's favourite music. On the other hand, the mothers may try to overcome their infants' reduced interest in the mother's favourite music (see section 6.3.3), by touching them in synchrony with the musical beat and involving them physically like in a dance.

The categories of the infant's synchronous behaviours show that physical contact plays a more important role than kind of music when synchronising with the beat. Thus type of music does not affect the infants' category of synchronous behaviours, as predicted. In fact, in the no-touch contexts infants match with the beat mainly through their hand movements, in particular during the infant's favourite music. This is not only true for taped music, but also holds in the no-touch context in interaction with songs when infants match often the beat through their hand movements. However, in the live song context, they also produce leg movements. On the other hand, in the touch contexts infants use mostly head and body to match the beat. As far as concerns interaction with songs, infants display this pattern only at 7-8 months. This suggests that infants match the beat especially not only according to the context of the interaction, but also as a function of the infant's age.

During interaction with taped music, mothers and infants show to be able to synchronise with each other's behaviours, as anticipated. Interestingly, mothers and infants appear to produce a higher percentage of behaviours in synchrony with each other during the infant's favourite music compared to the mother's music, although the mothers show this pattern only in the absence of physical contact. This confirms the prediction that mothers and infants would synchronise more often with each other during the infant's rather than the mother's favourite music. Across conditions, mothers and infants appear to compensate each other's

behaviours. For instance, in the no-touch contexts mothers produce a high percentage of synchronous behaviours with their infants' behaviours, whereas infants produce less synchronous behaviours in synchrony with their mothers. The opposite pattern holds in the touch context. Interestingly, this is also true in interaction with live songs where the partners of the dyad appear to be affected by context in relation to their synchronisation with each other's behaviours. However at 7-8 months the partners of the dyad produce a similar amount of synchronous behaviours, suggesting that at this stage the interaction has become more symmetrical and the partners of the dyad contribute fairly equally to the attunement of the overall interaction. With respect to accuracy, the partners of the dyad match more often each other behaviours at 40ms latency rather than 80ms. This is similar to what happens in interactions with songs. Hence, both partners tend to synchronise their behaviours closely with one another in musical interactions either with live songs or with taped music. Also both partners tend to produce more synchronous behaviours with each other which also turn out to be more accurate at 80ms latency during the infant's favourite music suggesting that they are more used to interacting with each other with the infant's favourite music. This therefore partially refutes the prediction that type of music would not affect the partners' accuracy with each other's behaviours.

When the musical tempo of taped music is considered, it appears that during slow tempos, i.e., *largo* and *adagio*, mothers synchronise very frequently with their infants' behaviours. By contrast, infants synchronise less often with their mothers' behaviours during those tempos. In interaction with live songs, the partners show the same pattern with the *largo* tempo only, because mothers do not sing at the *adagio* tempo. However, during medium to fast tempos, i.e., *andante*, *moderato* and *allegro*, infants produce more synchronous behaviours with their mothers compared to slow tempo music. Also in interactions with songs, infants produce a higher percentage of synchronous behaviours with their mothers' at the *andante* and *moderato* but not at the *allegro* tempo. Interestingly, in interactions with both songs and taped music during *largo*, *andante* and *allegro* tempos the partners also appear to be more accurate with each other compared to the other tempos. Therefore, with respect to musical tempo, the partners of the dyad appear to complement one another in musical interactions. In particular with slow tempo music, mothers are more oriented to their infants, whereas with medium to fast tempos infants are more oriented towards their mothers producing several behaviours in synchrony with them. So it could be that mothers use variations in tempo during songs and taped music interactions with their infants not only to

attract their infants' attention and to regulate their homeostatic states, but also to facilitate the attunement of both partners in the interaction.

The kinds of behaviours mothers perform to match with their infants seem to be related to kind of music rather than physical contact. In fact, during the infant's favourite music mothers synchronise with their infants mostly through cyclical behaviours, as predicted. By contrast, during the mother's favourite music, mothers match their infants' participation mainly through single gestures. However, in the touch context they synchronise equally through single and cyclical behaviours. Interestingly, in interactions with live songs, mothers synchronise more often with their infants' behaviours through cyclical behaviours but this only holds at 3-4 months. Therefore, once again mothers use cyclical behaviours to emphasise a context specifically addressed to the infant, which facilitates the interlocking of their activity with younger infants. By contrast infants perform single gestures to synchronise with the other partner across conditions and interactions with both live songs and taped music. This indicates that infants organise better single actions in synchrony with their mothers than other kinds of behaviours. Moreover, this result refuses the expectation that infants would perform more cyclical behaviours in synchrony with their mothers' behaviours during the infant's favourite music.

The categories of behaviours mothers and infants organise more often in synchrony with each other appear to be mainly related to physical contact and to some extent to the kind of music. In fact, during the no-touch contexts mothers use mostly head, body and limbs to match with their infants. In both touch contexts, mothers produce several synchronous behaviours in contact with their infants, in particular during the mother's favourite music. Therefore, once again, it emerges that during the mother's favourite music they touch their infant's body to match their activity, probably to involve them directly in the interaction and prompt attunement. This partially contrasts with the prediction that kind of music would not affect the mothers' categories of synchronous behaviours with the infant. By contrast, in the no-touch contexts infants synchronise with their mother's participation through hand movements especially, although with the infant's music they also use their head/body to match their mothers' behaviours. In the touch contexts, infants use mostly their head/body to match their mothers, and again with the infant's favourite music they also use their leg. Similarly to interaction with infant's favourite taped music, in interactions with songs infants move their head/body in the absence of physical contact, but produce hand gestures in the touch contexts, to match their mothers' behaviours. Thus infants may produce a wider variety

of synchronous behaviours with their mothers during the infant's favourite music because in that case they are more familiar with the patterns of the interaction. On the other hand, during the mother's favourite music infants are often actually moved and touched by their mothers. Thus head and body are the only category of behaviours left to them to match with their mothers. In this case infants refrain from participating because the mother's music is not part of the dyad's normal repertoire.

6.5 Summary of the chapter

This chapter examined mother-infant interaction with taped music, focusing on the tempo of musical events, their physical and communicative-affective behaviours, as well as their synchronisation with self, the musical beat and the partner.

In section 6.2 the tempo of the infant's favourite music was contrasted with that of the mother's favourite music and a clear distinction emerged between the two groups of dyads. In fact, the ES infants prefer faster tempos as their own favourite music, whereas the ES mothers choose medium to slow tempos as their own favourite music. By contrast, the musical tempo of both partners of the GS dyads is similarly oriented towards medium to slow tempos for both the infant's and the mother's favourite music. This suggests that their musical preference is related to the kind of music they are exposed to. The choice of different musical tempos may reflect their cultural background.

In section 6.3 the mothers' and infants' physical behaviours in interaction with taped music were considered. It was found that both partners' level of activity is related to physical contact. Infants' level of activity is higher in the absence of physical contact, whereas their mothers' is higher with physical contact. Therefore physical contact plays a differential role in the level of activity of the partners within an interaction with taped music and this turns out to be similar to interactions with live songs. Infants produce more cycles during the mother's favourite music, whereas mothers produce more cycles during the infant's favourite music. Also in interactions with songs, mothers use several cyclical behaviours, suggesting that cycles may be a way to communicate with their infants and to emphasise the infant's 'special music'. Interestingly, both partners' physical participation is affected by the tempo of the music. Mothers are more active during faster tempo, but they produce a higher percentage of cycles during *largo* and *moderato* tempos. On the other hand, infants are very dynamic during *adagio* tempo music, and their cyclical activity is similar across tempos although they perform the lowest percentage of cycles during the *moderato* tempo. Thus it

emerges that, similarly to interactions with songs, there is not a clear-cut relationship between level of activity and amount of cyclical behaviours. When their communicative-affective behaviours are taken into consideration, it turned out that mothers smile longer during the infant's favourite music and display more affectionate behaviours during the mother's favourite music. This suggests that mothers treat the infant's favourite music as infant-directed in nature, in contrast to their own favourite music which is more like adult-directed music. Infants smile longer, vocalise more often and touch their mothers more than themselves with their own favourite music. Similarly, infants display longer happy states and high engagement during the infant's compared to the mother's favourite music. This suggests that infants recognise and prefer their own favourite music, showing enjoyment and engagement, compared to the mother's favourite music. Also in interactions with live songs, mothers and infants display similar patterns particularly at 3-4 months, suggesting that there are similarities between interactions with live songs and the infant's favourite taped music.

In section 6.4, the mothers' and infants' synchronisation were measured. Interestingly it turned out that both partners display more accurate self synchronisation in the touch context with the infant's favourite music. This suggests that, in order to organise their behaviours internally within an interaction, both partners need to be in a familiar context, e.g., the infant's favourite music, and have physical contact. By contrast, the mother's favourite music is unusual for the interaction, and infants may be disoriented, whereas mothers may be too concerned about their infants' states to co-ordinate their behaviours internally. On the other hand, in interactions with songs, infants produce more frequent and more accurate self-synchronous behaviours in the no-touch context compared to the touch one. Thus infants organise their behaviours slightly differently in interactions with live songs versus taped music.

The partners' synchronisation with the musical beat reveals that overall both partners are more accurate with the mother's favourite music than the infant's music. Although mothers are more precise perhaps because more familiar with their own music, infants may be led by their mothers' temporally co-ordinated stimuli to synchronise accurately with the beat. However, when we look more in detail at the partner's synchronisation with the beat, it emerges that mothers and infants are more likely to match before the beat during their own favourite music. Also in interactions with songs at 3-4 months in the touch context, infants synchronise exactly on the beat. This indicates that familiarity and musical preference are important aspects of the mothers' and infants' accuracy with the musical beat. With respect

to the amount of synchronous behaviours, it emerges that both partners produce more synchronous behaviours at 40ms latency rather than 80ms. This suggests that they tend to cluster their behaviours close to the beat. In general, mothers match the beat more often with the mother's favourite music whereas infants do not display much difference between the two kinds of music. Thus infants' familiarity with the music is important but is not crucial for the amount of synchronous behaviours. Interestingly when we look at the musical tempos, mothers' and infants' amount of synchronous behaviours is directly related to the rate of music, i.e., the faster music, the higher number of synchronous behaviours. Therefore faster music seem to lead mothers and infants to match the beat more frequently. Also in interactions with songs both partners of the dyad display a similar pattern. Thus it seems that in relation to the musical tempo and the amount of synchronous behaviours with the beat mothers and infants are prompted similarly in interactions with live songs and taped music. Interestingly, it is at 40ms latency that mothers and infants show more frequent synchronisation. Also, in interactions with live songs, mothers and infants tend to cluster their behaviours closely on the beat. Chi square analyses show that, aside from the ES2 mother, none of the partners synchronise significantly with the beat. Across conditions, mothers show no significant synchronisation with the beat in the no-touch context with the infant's favourite music, suggesting that in that context mothers are more focused on their infants' than the music. Thus similarly to interaction with songs mothers do not synchronise significantly with the beat in the no-touch context with taped music. Infants do not synchronise significantly across any of the conditions. Interestingly in the no-touch context with the infant's favourite music infants display a significant effect in the opposite direction, i.e., they produce significantly less behaviours in synchrony with the beat than would be expected, which is similar to the interaction with live songs. This suggests that infants might miss the musical beat regularly, or produce systematically more behaviours in the gap between beats almost syncopating with the beat. The partner's synchronisation with the beat in relation to musical tempo shows that the infants do not synchronise significantly with the beat in any of the musical tempos. On the other hand, mothers synchronise significantly with the beat during *adagio* and *allegro* tempos. So it seems that during medium tempos mothers have more difficulty identifying and anticipating the beat. The reason for this may lie in the fact that in this case the medium tempo is perceived as neither too slow nor too fast and as such the mothers may not be able to form a clear enough representation of it. On the other hand, the medium tempo may serve to set the pace of the interaction, thus becoming integrated with it. Therefore it seems that the musical tempo affects how the mothers organise their synchronous behaviours with the beat.

Overall mothers' and infants' kind of behaviours in synchrony with the beat are mostly affected by physical contact. During the no-touch contexts mothers match the beat with single gestures, whereas in the touch contexts they do so with cyclical behaviours. On the other hand, infants synchronise mainly with single gestures, but in the no-touch contexts they also often match the beat with cyclical behaviours. Also in interactions with live songs mothers and infants display the same kinds of synchronous behaviours with the beat as a function of context. Interestingly, during the infant's favourite music, mothers use a wide variety of cycles to match the beat, but with the mother's favourite music they produce less variety of synchronous cycles which are in direct contact with the infant's body. Therefore mothers may convey the temporal structure of their own favourite music touching their infants rhythmically, whereas they use different temporally co-ordinated modalities during the infant's favourite music. By contrast, infants produce mostly leg cycles and hand waving in synchrony with the beat during the mother's favourite music. During the infant's favourite music they produce less cycles compared to the mother's music, and in particular they move their legs and hands in cycles. Thus infants appear to organise their cycles differently in relation to kind of music which may be due to their familiarity with the music or its tempo. The mothers' categories of synchronous behaviours reveal that in the touch context they produce a higher amount of behaviours directly in contact with their infants with the mother's favourite music. Interestingly, in interaction with live songs mothers do not touch their infants as often to convey the musical beat. Thus once again, mothers appear to make more effort to involve directly their infants with the mother's favourite taped music, perhaps because infants are less familiar with its temporal structure. On the other hand, infants' categories of synchronous behaviours with the beat seem to be affected by physical contact. In fact, in absence of physical contact, infants match the beat through hand behaviours, whereas in the touch context they do so with their head and body. No similarity emerges in this case with interaction with live songs, suggesting that infants organise the parts of their body differently to match the beat when exposed to taped music versus live songs. On the other hand, infants' somewhat older age may also play a role in the co-ordination of behaviours with the beat.

Finally, when synchronisation with each other's behaviours is considered, it turns out that although at 40ms latency the partners do not show much difference in their accuracy, at 80ms latency they appear to be more accurate in the context of the infant's favourite music. Thus the partners seem more capable of smooth and close attunement with the infant's favourite music, probably because they use it more often for interaction. The amount of

behaviours in synchrony with the partner appears to be related mostly to physical contact and also to the kind of music. In fact, mothers produce several behaviours in synchrony with their infants during the no-touch contexts, whereas their infants match their mothers more frequently in the touch contexts. In the absence of physical contact, mothers appear to be concentrated on their infants and probably try to ensure a harmonious interaction. On the other hand, when there is physical contact, mothers show a smaller percentage of activity and it is possible that in this way their infants can contribute more to the establishment of synchronous interaction. Interestingly, infants produce more synchronous behaviours with their mothers during the infant's favourite music, suggesting that their own favourite music is an inherent part of the interaction. Also in interaction with live songs, mothers and infants display similar patterns of synchronous behaviours with one another, suggesting that interactions with the infant's favourite taped music share some similarities with interactions with live songs. With respect to musical tempo, it emerges that with slow tempos, i.e., *largo* and *adagio*, mothers are more focused on their infants and produce a high amount of behaviours in synchrony with their infants. On the other hand, during medium to fast tempos, i.e., *andante*, *moderato* and *allegro*, infants produce a high level of synchronous behaviours with their mothers. Again, in interactions with songs, mothers also produce more synchronous behaviours with their infants' behaviours with the *largo* tempo, and infants are more synchronous with their mothers' behaviours during *andante* and *moderato* tempos. Thus it could be that during these tempos mothers and infants are somehow more oriented towards each other and hence towards the interaction, whereas with the other tempos they are more focussed on the music. The kind of behaviours mothers produce to match their infants' behaviours are related to the kind of music principally. In fact, mothers perform mostly cyclical behaviours during the infant's favourite taped music, like in interactions with live songs, whereas single gestures with the mother's favourite music. Thus once again mothers emphasise their infants' special music with cyclical activity which they perform to interlock and attune with them. By contrast, infants match their mothers' through single gestures mostly similarly to interactions with songs. The categories of infants' synchronous behaviours reveal that they produce a wider variety of behaviours during the infant's favourite music, perhaps because they are more familiar with the patterns of the interaction and can participate with whole their body.

Overall it emerges that the infant's favourite taped music shares many similarities with interactions with live songs, suggesting that the infant's favourite music has a special place in the interaction between mother and infant. In fact, with this music both partners appear to be

able to relate to each other, and music appears to be more integrated in the interaction. Infants seem to recognise their own favourite music and participate with enthusiasm and engagement. On the other hand, during the mother's favourite music, mothers have to make an effort to integrate it into the interaction, and often they involve their infants more directly like in a dance.

CHAPTER SEVEN

General Conclusions and Discussion

With respect to interactions in which mothers talk to their infants, almost every aspect of mother-infant interaction has been extensively documented, but this thesis is the first to explore at the same level of detail interactions in which mothers sing to their infants. The naïve reader will probably have thought that musical interaction with infants is mainly in the form of lullabies to soothe them into a state of sleep. But this is not so. In fact, playsongs turn out to be more frequent than lullabies (Trehub & Trainor, 1998). My argument is that music plays a vital cognitive function in helping infants learn about hierarchical structure and segmentation, in much the way that early mother-infant speech interaction plays a similar role. Moreover, due to the fact that infants are very sensitive to repetition, it could be that early on music is even more important than speech, because it involves consistent cyclical recurrences of between-phrase and within-phrase units.

Due to the fact that mother-infant musical interaction has hitherto been a relatively unexplored domain, I opted in the thesis for an initial in-depth, micro-analytic observational approach rather than an experimental one. Furthermore, like many early languages researchers, I chose a naturalistic over a laboratory setting. While there are many advantages with the micro-analytic, semi-observational approach, there are clearly disadvantages too. A clear advantage is that the level of detail of the data means that one has a much fuller picture of the domain of interest, making it possible to discover the most relevant trends. One disadvantage, however, is that because of the nature of the data, they only sometimes lend themselves to statistical analysis. Thus, I was only able to measure significance levels in respect of part of the data in the thesis. A second disadvantage is that it is obviously very difficult to lift the huge body of detailed information to a more general level of description. This is not peculiar to the domain of musical interaction. Indeed, in many domains of cognitive development, the micro-analytic method had to be subsequently complemented by more strictly controlled experimental methods designed to yield data that lend themselves better to statistical analysis (Siegler, 1996). Despite the difficult challenge of lifting the micro-analytic data to a more general level, this is my chosen focus for this final chapter. While I examined different aspects of the results in separate chapters, clearly my findings are deeply interrelated, and it is the relationship between the different analyses that I will endeavour to bring forth in the following pages.

Several authors (see Stern et al., 1977, Beebe et al., 1985; Beebe et al., 1992), have noted the importance of the beat established by the mother and the fine temporal organisation of early social interaction. So far researchers have analysed these aspects only in interactions in which mothers talk to their infants but not in those when mothers sing or play music to their infants. The focus of my thesis was to examine the details of the fine-tuned temporal structure of mother-infant interaction as well as the beat established by the mother when she sings songs or plays taped music to her infant. On the basis of an extensive review of the literature on the theory of music, on the structure of songs, on the psychology of tempo, and on mother-infant interaction in the context of language, I formulated a number of hypotheses. These were tested over five months of the lives of four mother-infant dyads. Because of the level of detail of the micro-analysis, as well as its labour-intensity and time-consuming nature, this initial foray into the domain of mother-infant musical interaction obviously had to focus on a small number of dyads. In particular this thesis examined the following issues:

- 1) whether mothers use a consistent musical tempo of around 500-700ms when singing or playing taped music in interaction with their infants, across different contexts and different ages, whether the musical tempo affects the interaction, and if so, how; whether mothers emphasise the temporal structure of their songs when singing to their infants, with particular attention to beat, metre and phrasing organisation.
- 2) how mothers and infants participate in musical interactions with attention to their physical behaviours in order to examine their level of activity and cyclical actions; measure the communicative-affective behaviours of both partners, as well as the emotional states and degree of engagement of the infant; examine how the partners of the dyad participate in the interaction in relation to the temporal structure of the songs.
- 3) the extent to which mothers and infants synchronise during musical interaction with self, with the musical beat and with the other partner, with attention to their accuracy and amount of synchronous behaviours.
- 4) the similarities and differences between live songs and taped music in mother-infant interaction in respect of musical tempo, physical and communicative-affective participation, as well as synchronisation with self, the beat and the partner.

Chapters 3-6 present the full details of my research into the temporal structure of mother-infant musical interaction. Rather than repeat at length my hypotheses and findings

(summarised at the end of each individual chapter), my aim in this concluding chapter will be to examine my results in a more integrated fashion, as well as to point to the shortcomings of a qualitative study and to make suggestions for future experimental research.

7.1 Major findings

One of the most important discoveries from my thesis is with respect to hierarchical structure. A detailed analysis of the temporal structure of the songs revealed that mothers emphasise the metrical and phrasing structure of their songs, both acoustically through their singing, and behaviourally by synchronising their physical and communicative-affective behaviours with the beats relevant to the temporal structure of the song. In doing so, mothers actually provide for their infants a means of segmenting the flow of the song, much as they do with respect to the segmentation of speech. How do mothers convey hierarchical structure to their infants? Interestingly, not the way it is done in traditional Western music itself, but much more like an orchestral conductor does. Indeed, in music it is the downbeats that represent the stronger beats, whereas upbeats mark the weaker elements. By contrast, my findings indicate that when mothers sing to their infants, they emphasise the upbeats, i.e., the ones that are usually regarded as weaker. This turns out to be similar to what occurs in the context of an orchestral performance. Conductors, it seems, make a special effort to signal to the players when the upbeats occur so that the members of the orchestra are actually successful in coming in together on the downbeat. In other words, by stressing the upbeat, mothers give cues to their infants that the main beat is about to follow. It is noteworthy that when our conductor accompanied the mother's songs with a tapping movement, he explicitly remarked that the mothers were singing with the very same pattern as used in orchestral performances. He also commented on the importance of the mothers' strategy, because it is likely to enable the infant to anticipate and time his participation to match the relevant beats of the song. In this way, the structure of the songs becomes predictable, which may facilitate the infant's processing of the input.

What is it that mothers actually do? First, the results reported in Chapter 3 indicate that mothers explicitly (although probably unconsciously) mark the boundaries both between phrases and within phrases. They do so by extending the duration of certain beats over others. Indeed, it is the end of the phrase, the 8th beat, and the middle of the phrase, the 4th beat, that they treat differently to the other beats, thereby providing clues for their infant as to the segmentation of the song. Interestingly, when mothers stress the metrical structure of the song through their singing, they do so irrespective of context or the infant's age,

suggesting that it is a robust trend in the mothers' singing to young infants. Similarly, mothers synchronise their behaviours to match exactly the same beats that they extend while singing (see Chapter 5). These behavioural markers that match the stress on the upbeats are yet another indication that may signal to their infants that the main beat will follow. Thus, mothers use different modalities to convey the temporal structure of the song.

Are infants sensitive to the segmentation of the songs at the level of smaller units? My findings suggest that they indeed have sensitivity to the metrical structure of the song. In fact, when they match their behaviours with the musical beat a fascinating picture emerges. Infants synchronise significantly more often with certain beats over others, sometimes are upbeats and other times the downbeats. More interestingly, such upbeats and downbeats are vital to the temporal structure emphasised by their mothers. In fact, they match significantly more often the 1st, 4th, 5th and 8th beats. In this way infants not only show themselves to be sensitive to those beats mainly stressed by their mothers, i.e., 4th and 8th beats, but they also synchronise significantly more often on the 1st and 5th beats, i.e., the main downbeats. This indicates that they are sensitive to their mothers' signalling via the upbeats that a main beat is to follow, and the infants come in with their participation on the main beats of the songs. Thus, through their behavioural participation, infants display their sensitivity to the segmentation of the musical event.

Infants match the beat mainly through single gestures, especially those which involve hand and leg behaviours at 3-4 months and head and body behaviours at 7-8 months. By contrast, their mothers synchronise with the beat mostly through cyclical actions which involve different modalities. In fact, they perform cyclical actions of their own body such as head nodding and body bouncing, cycles through which involve touching their infants, i.e., finger tickling, cycles in direct contact with the infant's body, i.e., bouncing and waving the baby's limb as well as bouncing the baby's body, and cyclical movements of the toy, i.e., toy bouncing and waving. These cycles appear to change and are modified according to the presence or absence of physical contact and as a function of the infant's age. We can thus conclude that infants are able to integrate information coming from different modalities, e.g., acoustic, visual, tactile and kinaesthetic, and organise their participation in accordance.

Another notable finding from the present research is that mothers' and infants' physical and communicative-affective behaviours all reflect not only the metrical structure of the songs, but also importantly the more detailed phrasing structure of the songs. In fact, phrasing

structure represents another level of segmentation of the song that allows infants to divide the musical event into units, thereby facilitating their musical perception. Although statistical analysis revealed that variation of phrase duration is not due to the phrase per se, but to the extension of certain specific beats within the phrase, I found a significant effect of musical tempo on phrase duration as well as a significant interaction between phrase duration and musical tempo of the song (see Chapter 3). This suggests that when singing the mothers modify the length of the phrase according to their position in the song across the different tempos. Pairwise comparisons showed that when using the *moderato*, *allegro* and *presto* tempos mothers significantly extend the duration of the 4th phrase. On the other hand, when the mothers sing at the *andante* tempo, they extend the 2nd phrase of the song. This is an important finding because it means that when mothers sing songs at a specific tempo, they are more likely to extend the duration of a particular phrase compared to others, thus making themselves more predictable to their infant.

Both mother and infant show a significant effect of phrase with respect to their level of participation in the musical interaction as a function of context, age and musical tempo. In particular, the findings of Chapter 4 showed that it is the 1st phrase of the song in which both partners display significantly higher levels of activity compared to the other phrases of the song across conditions. However, the infants produce a significantly higher level of activity in the 1st compared to the 2nd and 3rd but not the 4th phrase, showing that they also perform several behaviours during the final phrase of the song. Interestingly, when the musical tempo of the song is taken into consideration, it emerges that both partners show a significant effect of phrase on their level of activity in the phrases of the song across musical tempos. Infants display the same pattern with respect to context and age whereas the mothers show a significant interaction between musical tempo and phrases of the song. In fact, they perform a significantly higher level of activity in the 1st phrase of the song with *largo*, *andante* and *allegro* tempos. Again the significant level of the mothers' activity in the 1st phrase in some tempos suggests that they make themselves more predictable to their infants not only by the phrasing structure of their songs, but also in terms of their physical behaviours, thereby enhancing the flow of the interaction. Also when mothers and infants synchronise with the musical beat, they distribute significantly their synchronous behaviours with the beat across the phrases of the song as a function of musical tempo but not in relation to context and age. In fact, the analysis of variance showed for both partners a main effect of tempo as well as a significant interaction between phrase and musical tempo. Thus not only do the partners synchronise more often with respect to certain musical tempos over others, but they also

produce more behaviours in synchrony with the beat in certain phrases as a function of the musical tempo.

When mothers and infants synchronise with each other, the phrasing structure of the song also turned out to help the partners organise their behaviours. The analysis of variance of the effect of phrase on the number of synchronous behaviours with each other produced by the partners did not show a significant effect across conditions. However, when musical tempo is considered, there is a main effect of tempo for both partners as well as significant interaction between phrases and musical tempo (for infants, this doesn't quite reach significance). Again, the musical tempo of the songs plays an important role in aiding the partners to co-ordinate their synchronous behaviours with each other across the phrases of the song. Phrasing, which is situated some halfway between the whole song and the local level of the beat, is yet another level of the temporal structure of the songs and is likely to impact on the structure of dyadic interaction. One can even speculate that this middle-level structure of temporal organisation may contribute towards the infant's understanding of turn-taking. The implicit structural information conveyed to the infant does not only occur at the level of the delivery of the song itself. It also is conveyed by the variety of the tempos used, by the mother's physical and communicative-affective actions, as well as by her behavioural synchronisations.

In all of the empirical chapters, tempo was shown to play a crucial role in musical interaction. My findings indicate that, contrary to the claims of other authors, mothers do not use a consistent tempo but tend to vary tempo as a function of the state of their infant. The most common tempos turned out to be *andante* and *allegro*, but variation was the rule rather than the exception. Faster tempos may have been used to attract and sustain the infant's attention, whereas slower tempos may have been employed in the service of soothing the infant and maintaining a homeostatic state. Medium tempos, on the other hand, may have served a different purpose. It was proposed that they function as a pace setter for the overall interaction, neither too slow nor too fast, facilitating the general flow of communication between the partners of the dyad. Overall, musical tempos turned out to be important, not only in relation to the phrasing structure of the song, but also for both partners with respect to the differentiation of levels of synchronous behaviours with the musical beat as well as with the other partner. This held for both songs and taped music.

My findings also suggest that certain tempos play different roles in mother-infant interaction. This held particular for the results reported in Chapter 5 for live songs, but less so for taped music in Chapter 6. The results indicate that during *andante* tempo both partners do not synchronise significantly with the beat. However, sometimes they show a significant effect in the opposite direction. By contrast, the infants produce a high amount of synchronous behaviours with their mothers during the *andante* tempo. Infants also synchronise significantly more often with their mothers' behaviours in the 3rd phrase of the song at the *andante* tempo. When accuracy is considered, it emerges that the partners of the dyad are very precise when synchronising with each other's behaviours during the *andante* tempo. By contrast, with *allegro* tempo only the mothers synchronise significantly with the beat. Interestingly both partners produce a high amount of behaviours in synchrony with the beat but a small amount of behaviours in synchrony with each other. But there is a difference between amount of behaviours and accuracy of behaviours: both mothers and infants show high levels of accuracy in synchronising with each other's behaviours.

7.1.1 The function of musical tempo

What is the function of these differences in tempo? In my view, although of course this remains necessarily speculative, the faster *allegro* tempo is employed as a means of grabbing the infant's attention and of helping them organise their behaviours. In fact, according to the theory of Jones (1982) and Jones and Boltz (1989), infants are more sensitive to faster tempos than slower ones. Therefore, not only might infants perceive faster tempos more easily as these authors claimed, but it is likely that such tempos also help them to co-ordinate and organise their behaviours. On the other hand, the *andante* tempo seems to be used in the service of sustaining interaction. In fact, because the *andante* tempo corresponds to what Fraisse (1964) deemed to be spontaneous tempo (which is measured by the natural speed of tapping) and preferred tempo (which is the speed of events perceived as natural), it may be that the *andante* tempo represents the most natural rhythm for the partners to relate to one another. In sum, the *allegro* tempo seems to have a special attentional function for the infant, focusing both partners on the music and helping them to relate to each other through music. By contrast, the *andante* tempo seems to have an interactional function, with less focus on the music and more on the other partner of the dyad. In this case, both partners reduce their overall activity which may then help them to re-establish the homeostatic state of the infant. It is worth reiterating that the vital role of tempo was also revealed by the fact that in many analyses in Chapters 3-5, tempo turned out to have a marked effect.

7.1.2 The function of context and age

What about the effect of context and age? Although it is not possible to draw any definite conclusions about context and age because to some extent they were confounded, some of the major effects can be listed. Context turned out to affect mothers' and infants' level of activity, kind of cyclical actions as well as amount and accuracy of synchronisation with self, the musical beat and the partner. This effect was similar across interactions with both live songs and taped music. With respect to age, mother and infants seemed to be somewhat affected in their level of activity, amount and kind of cyclical behaviours, as well as synchronisation with self, with the musical beat and with the partner. Accuracy was more precise when infants were younger, but level of activity and amount of cyclical behaviours showed a slight increase with age. Thus it appears that physical contact and age have some effect on how mothers and infants participate in the musical interaction. In particular, in the presence of physical contact music seems more integrated into the interaction compared to when it is absent. With age, interactions with live songs tend to show developmental changes similar to those found in linguistic interactions. Although some interesting effects emerged in relation to context and age, it seems that those related to physical contact are stronger than those related to age. However, to confirm these impressions it would be necessary to test such effects more precisely with an appropriate experimental design and a larger group of participants.

In sum, the singing context provides the infant with a number of overlapping, importantly redundant cues as to the hierarchical, temporal structure of the interaction. Even physical actions performed by the mother play a vital role. My analysis highlighted the co-ordination of the cyclical movements of the different parts of the mother's body, which are in tight synchrony with the way in which she also moves cyclically all the parts of the infant's body. In fact, some 70% of the mothers' total behaviours were cyclical in nature and the majority of those, i.e., around 60%, were organised in synchrony with the beat and the infant. In my view, because of the temporal co-ordination of this variety of the mothers' physical actions, infants experience high levels of contingency and coherence, enabling them to integrate information from different modalities. The simultaneous integration of information has been recently shown to be exceedingly important in developing stable representations in the brain (Csibra et al., 2000), so this again suggests that the context of musical interaction may well play a crucial general role in infant cognitive development.

7.1.3 Taped music versus live songs

All of my conclusions thus far apply to contexts in which the mothers sang songs of their choice. Does the same hold for taped music, a condition introduced to verify whether the data were specific only to live songs? Chapter 6 examined some aspects of this question in a context in which the beat is external to the mother. The findings showed that mothers chose musical pieces that provided a narrower range of tempos compared to their live songs. Not only did the mothers choose less *andante* songs but, like live songs, the *andante* tempo produced less synchronous behaviours on the part of both mother and infant especially. A marked difference of tempo emerged with respect to the choice the mothers made for their infant's favourite music compared to their own favourite music. For the latter, all the tempos were used to roughly the same extent (when the data were collapsed across contexts). However, for the infant's favourite music, *allegro* turned out to be by far the most popular, followed by the *largo* tempo; the *adagio*, *andante* and *moderato* tempos were almost non-existent. On the other hand, when the partners' activity is considered in interaction with taped music, some similarities with live songs emerge regarding context. For instance, in the absence of physical contact mothers show a lower level of activity in the no-touch context compared to the touch one, whereas the infants display the opposite pattern. This holds for both live songs and taped music. Moreover, the infants produce a higher amount of cyclical behaviours in the no-touch context compared to the touch one in both kinds of musical interaction.

The temporal window for synchronising with the beat was also affected by the choice of infant's versus mother's favourite songs. During the latter, infants were more likely to synchronise 80ms after the beat, whereas with their own favourite music synchronisation tended to occur more often 40ms before the beat. This is probably due to the fact that the infant is more familiar with the general temporal structure of the type of song that the mother chose for his favourite music, compared to the less familiar songs the mother liked for herself. The infant's favourite taped music shows very similar results to my study with live songs, highlighting the important interactional role of music. For instance, when synchrony between each other's behaviours is considered, at 40ms the partners show no difference, but at 80ms latency they display better accuracy in the contexts with the infant's favourite music than with the mother's music. Infants also produce a higher amount of behaviours in synchrony with their mothers during the infant's favourite music compared to the mother's music. So infants' preference for and familiarity with a specific type of music may play a

vital role in how successfully they segment and structure the musical interaction. And this may, in turn, have an effect on their more general social interaction.

The mothers' behaviours also mark differences in types of music and types of context with the infant's favourite music as they do with live songs. For instance, in interaction with live songs, the mothers do not synchronise significantly with the musical beat in either of the contexts. This also occurred in interaction with taped music with the infant's favourite music, when the mothers failed to synchronise significantly with the beat in both contexts. Moreover, during the infant's favourite music, mothers display long periods of smiling, and the highest amount of cyclical behaviours. Similarly in interaction with songs, mothers show very long smiling and the majority of their activity is cyclical. Thus mothers may consider the infant's favourite taped music as being similar to infant-directed live songs, in contrast to the mother's favourite music which is more adult-directed. Also with their own favourite taped music, infants display patterns of communicative-affective behaviours, emotional states and degrees of engagement similar to their behaviours with live songs. Moreover, similarly to interaction with live songs, in interaction with the infant's favourite taped music, infants synchronise with their mothers' behaviours through head and body behaviours in the no-touch context and through hand behaviours in the touch context.

7.2 What drives the interaction in musical context

In general, mothers and infants seem to modify their behaviours in terms of amount, kind, synchronisation and accuracy during musical interactions. But what is making mothers and infants to do so? We have seen that the hierarchical structure of the songs moulds how both partners of the dyad relate to the interaction. In fact, it could be that the metrical and phrasing structures of the songs influence how the mothers and infants organise their behaviours in musical interactions. On the other hand, it is possible that the mother herself is the driving force of musical interactions because she is the one establishing the beat and organising her behaviours in relation to the musical structure of the song. It might thus be thought that her infant merely adjusts to her behaviours. However, another factor that appears to affect the musical interaction is musical tempo. In fact, tempo seems to modify the pace of the interaction, with the main purpose of different tempos being either to attract the infant's attention or to re-establish his homeostatic state. Thus it could be that the driving force of the musical interaction is actually the infant himself, with the mother constantly adjusting to his states and needs. Her live songs as opposed to taped music seem most appropriate for this, enabling her to adapt easily to her infant's changing states. However,

most likely of all, the drive stems from the dynamical system of the dyadic interaction, with both partners playing a crucial but complementary role.

7.3 What drives the human sensitivity to music?

What drives generally our human interest in music? Music has multiple levels of structure: temporal structure in terms of beat, phrase, stanza and verse, and melodic structure in terms of pitch, prosody, melody and harmony. In this thesis I focused on temporal structure, but clearly melodic structure is equally important. Music also has multiple functions: cultural, social, emotional, communicative, and cognitive. How important is music in mother-infant interaction? Several theorists (e.g., Lerdahl & Jackendoff, 1983; Martin, 1972; Yeston 1975) have speculated that both music and speech are segmented at different levels and layered in a hierarchical structure. So, what is the difference between interaction with language and interaction with music? Is musical interaction merely the “icing on the cake” of normal linguistic interaction, or could it be used more purposefully for therapeutic ends? Obviously the present results cannot address these questions directly, but it is worth speculating on such issues in the service of future research. Perhaps because of its melodic contours, music makes it possible to emphasise the structure of the musical event, and ultimately of the interaction, through a great deal of repetition and redundancy which is somewhat less readily done through the linguistic medium. Take, for instance, the fact that there are a number of developmental disorders where researchers have reported a special interest in music by children with learning difficulties. Down’s syndrome is a case in point where older children have been shown to respond well to music (Cicchetti & Beeghly, 1990). Could the present findings be used to encourage parents of, for example, young infants with Down’s syndrome, to give a far more predominant role to musical interaction very early in development? It could be that such well structured musical interaction might be used to form the crucial foundations for their future linguistic interactions. In other words, my findings suggest that we should shift the focus of Special Needs educators from considering music as mere entertainment, to taking music also as a device for learning to structure the complexities of human interaction. Furthermore, in cases of poor contingent interaction seen, for example, in depressed mothers (see Cohn et al., 1986; Field, 1987), it is possible that therapists could encourage such mothers to make use of carefully chosen taped music (infant songs). In this way, despite their depression they might move spontaneously with the beat, thereby unwittingly providing social information to their infants. These are all issues that could be pursued in future, more structured research on mother-infant interaction with music.

7.4 Shortcomings of the study

Clearly, having opted for a micro-analytic semi-observational study, my thesis has some shortcomings which future research should address. First, the small number of dyads needs to be augmented. However, had I chosen a larger number, it would have been impossible to go into the level of detail which I believe is essential when initially exploring a new domain. Second, it is obvious that age and context were not sufficiently controlled in this initial exploration. This was mainly due to time and labour constraints experienced by a single researcher. However, as with any in-depth foray into a relatively uncharted domain, a qualitative approach was a crucial first step before more experimental procedures could be entertained. For example, this more qualitative approach was basically the initial one of Piaget and his disciples whose work other researchers were subsequently able to refine and test in experimental tasks with formal designs that are more compatible with statistical analysis. This type of approach also characterised early child language research (e.g., Brown, 1973) where again, a massive amount of semi-observational data on only three children were later used by numerous other researchers to generate strong hypotheses to be tested experimentally.

In retrospect, I recognise that the balance between the depth of data collection for individual mother-infant pairs and the number of pairs was not appropriate for the final research questions to which they were applied. In consequence, the results (while sometimes extremely promising) can only be suggestive, and I recognise that the assumptions of the statistical techniques I used were sometimes compromised by faults of experimental design. In part, the design faults (apparent with hindsight) arose due to the necessarily explorative nature of the project and the lack of existing work in this field. In part, also, they arose by too great an initial emphasis on the data collection itself rather than on the generation of testable hypotheses. The work in this thesis illustrates the need for subsequent more focused data collection across a larger number of dyads on precise but narrower theoretical questions. However, viewed within this framework, the current research has proved an invaluable scientific learning experience for the author and has opened a window on potentially exciting phenomena within mother-infant interaction.

7.5 Suggestions for follow-up experimental research

It is now time for more targeted research, and I suggest below some of the experiments that might be conducted in future as a follow-up from the detailed qualitative findings of the present thesis:

- 1) In my study, both partners of the dyad tended to display different amounts of cycles as well as different kinds of cycles as a function of age. It would be interesting to examine more precisely whether cyclical behaviours are more important with preverbal infants than later when infants start babbling. A cross-sectional experiment covering three groups of infants of 3, 7, and 12 months could be run, with mothers either singing to their infants or interacting through the means of language. The mothers' and infants' cyclical behaviours would be coded only in terms of their frequency, which would make a rapid analysis of the behaviour possible.
- 2) In order to find out how early infants show sensitivity to different musical tempos, newborns could be trained in a non-nutritive sucking habituation paradigm (using say the *allegro* tempo) and then assessed as to whether they dishabituate to a change in tempo (say the *moderato* tempo). A second level of parameter could be tested as to whether newborns discriminate better when it is their mother's voice that changes tempo or whether they are equally successful with respect to changes in tempo with taped music.
- 3) The effect of tempo emerged in my findings as a strong factor affecting interactions with both live songs and taped music. It would be important to check this effect in a more controlled fashion, by having a group of mothers sing to their infants at fast (*allegro*), medium (*andante*), and slow (*largo*) tempos. Would these differences in tempo affect the mothers' and infants' behaviours, with for instance mothers producing more hand cycles with slow tempos, and more head and body cycles with *andante* and *allegro* tempos? On the other hand, would the differences in tempo make infants perform more hand cycles with slow tempos, and more leg and head nodding with *andante* and *allegro* tempos? This would again be a cross-sectional study covering three age groups: 3, 7 and 12 months of age, to chart any developmental changes that occur.

- 4) To assess the broader effects of music on infant development, assessments should be made of cognitive function (e.g., the Bayley Scales of Infant Development, Bayley, 1993) prior to and following a period of intense musical interaction. Again, the three ages suggested above could be used in this study also.
- 5) To assess the effect of music per se, not confounded with interaction, assessment should be made of the differences between infants' behaviour in the presence of a prototypical musical interaction such as live songs versus their behaviour in the absence of music but in the presence of linguistic interaction.
- 6) To test the specific advantage of music in mother-infant interaction in atypical groups, e.g., depressed mothers, a group of such mothers could be given a programme of taped music that infants like, which could be compared with mother-infant interaction during linguistic exchange. These results could be compared with those of non-depressed mothers of typically developing infants.
- 7) Do infants of 7-8 months of age display cross-modal matching of, for example, a hand tapping the structure of music on a screen and the sound of the musical beat in their ear? Are they sensitive to mismatches in this respect? Apart from using preferential looking time measures, one could also take measurement of whether infants display behaviours with their legs and/or arms in synchrony with either the visual or auditory stimuli.
- 8) If one violates the phrasing structure of a song by, for example, extending the upbeat at the beginning of the phrase, are infants sensitive to this compared to the more natural extension at the end of the phrase of a song?
- 9) When mothers sing to adults, do they emphasise the hierarchical structure similarly to when they sing to their infants?

These are but a few of the issues that can now be addressed experimentally with infants, older children and even with adults. The field of musical perception and musical interaction is just at its inception and many exciting discoveries wait to be made. I hope that my thesis has provided some of the detailed foundational data for subsequent experimental work in this fascinating field of enquiry.

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APPENDIX

LIST OF ABBREVIATIONS USED WHEN CODING CATEGORIES

Usually they are typed next to the onset and offset time code

code+VH	Behaviour partially hidden from the view
VH+body part	Part of the body completely hidden from view
VH	Part of the interaction completely hidden from view
code+a	Half cycle
code+f	hand code, finger moving
code+f	leg code, foot moving
code+t	in contact with the baby's face, the mother touches his tongue
code+n	in contact with the baby's face, the mother touches his nose
code+e	in contact with the baby's face, the mother touches his ear

PROTOCOL OF THE MOTHER'S PHYSICAL BEHAVIOURS

Head movements

Nodding head, B03

Cycle movement of the head: up-down-up or vice versa, or backwards-forward-backwards or vice versa.

Shaking head, B04

Cycle movement of the head: left-right-left or vice versa.

Head up, B08

Single gesture of the head up.

Head down, B09

Single gesture of the head down.

Head side, B10

Single gesture of the head to side.

Head backward, B08b

Single gesture of the head backward from the baby.

Head forward, B09f

Single gesture of the head forward to the baby.

Body movements

Bouncing body, B00

Cycle movement of the body: up-down-up or vice versa. It might help in the measurement to look at the movement of the shoulders up and down.

Rocking body, B01

Cycle movement of the body: forward-backwards-forward or vice versa.

Swaying body, B02

Cycle movement of the body: left-right left or vice versa. Again looking at the shoulder movements might help to define the cycle, but this time is the turning movement. This is the only case in which even a non completed cycle might count as a whole cycle. It can happen because our interest is to follow the mother emphasis so when she dances she stresses the repeated movement with an uncompleted cycle. It will be still coded as cycle because part of the same category. It's the repetition of the movement the fundamental aspect that make it rhythmical pattern, therefore marked as a cycle.

Body forward, B11

Single gesture of the body forward to the baby.

Body backwards, B12

Single gesture of the body backwards from the baby.

Body side, B13

Single gesture of the side of the body.

Leg movements

Bouncing legs, B06l (left) and B06r (right)

Cyclical leg movement observed in the action of the knee: bend-stretch-bend or vice versa. It is present usually when the mother is dancing, but also when she is sitting on the floor.

Walking-dance, B07l and B07r

Cyclical leg movement observed in the action of the leg-foot: down on the floor-up-down. It happens when the mother stands and dances in the room, and the walking is characterised by a rhythmical structure.

Waving leg, B16l and B16r

Cyclical leg movement: left-right-left or vice versa. Usually the mother does this when sitting and holding the baby on her legs.

Tapping foot, B15l and B15r

Cyclical foot movement: up-down-up or vice versa. The mother might stand or sit, and the baby may be on her lap.

Leg down, B20l and B20r

Single leg gesture down.

Leg up, B21l and B21r

Single leg gesture up.

Leg side, B17l and B17r

Single leg gesture side ways.

Hand movements

Rubbing-Caressing, left hand C01, right hand C02

Cyclical hand movement: up-down-up or vice versa, or left-right-left or vice versa. The whole cycle is in contact with the baby's body or face

Patting, left hand C05, right hand C06

Cyclical hand movement: contact-away-contact. Because it might be difficult to understand when the first patting starts, it was found useful to measure this from the point of contact with the baby's body.

Tickling, left hand C22, right hand C23

Cyclical finger movement: contact-away-contact. Similar cycle as above but by fingers. Again the point of contact with the baby's face or body is important and it is easier to measure from this contact.

Activity Not in contact with the baby's body

Waving, left hand C09, right hand C10

Cyclical hand movement: left-right-left or vice versa. Cycle not in contact with the baby's body but presented in front of the baby's face.

Shaking, left hand C13, right hand C14

Cyclical hand movement: up-down-up or vice versa. Again a cycle not in contact with the baby's body.

Circling, left hand C04, right hand C03

Cyclical hand movement: circle designed in the air. It could be either in contact or not with the baby's body.

Clapping hands, C17

Cyclical hand movement: clapping gesture of both hands, measured from hand' contact to hand contact.

Activity In contact with the baby's body

Body:

Bouncing body G11

Cycle of the baby's body: up-down-up or vice versa. The mother can do this holding the baby either in direct contact with her body or at distance.

Shaking body G10

Cycle of the baby's body: left-right-left or vice versa. This is a cycle that the mother does when dancing with the baby, who, usually, is not in direct contact with her body.

Rocking body G20

Cycle of the baby's body: backwards-forward-backwards or vice versa. A cycle that the mother makes when holding the baby who is seated in front of her or on her knees.

Swinging body G15

Cycle of the baby's body again: backwards-forward-backwards or vice versa but with the mother acting as a swing for the baby.

Flying body G16

Cycle of the baby's body which usually is presented in circle, so the mother turns 360 degrees the baby flies out from her body. One full rotation is measured as one cycle.

Lift baby, G01

Single gesture of the baby's body, when the mother lifts the baby up.

Limbs

The limbs are coded looking at one limb at a time. This concerns the mother's activity with the baby's limbs.

Cycling, left G02l, right G02r

Cycle of the limb: bend-stretch-bend or vice versa. The mother moves the baby's limb like cycling.

Waving, left G04l, right G04r

Cycle of the limb: left-right-left or vice versa.

Shaking, left G05l, right G05r

Cycle of the limb: up-down-up or vice versa.

Circling, left G06l, right G06r

Cycle involving a circular motion of the limb. It is measured from the starting point of the circle to the same point of the circle.

Irregular, left G07l, right G07r

It refers to any cycle which doesn't have a specific direction or orientation that the mother makes while playing with the baby, but still has the cyclical pattern.

Up, left G08l, right G08r

Single gesture of the limb up

Down, left G09l, right G09r

Single gesture of the limb down

Side, left G10al, right G10ar

Single gesture of the limb side, either right or left

Rhythmical games with object/toy

Holds object/toy, C32

The mother holds an object or toy playing with the baby

Shaking-Wagging C30

Cycle of the toy/object: left-right-left or vice versa

Bouncing, C31

Cycle of the toy/object: up-down-up or vice versa

Squeezing C35

Cycle of the toy/object: press-release-press

Move up, C31u

Single gesture of the toy/object up

Move down, C31d

Single gesture of the toy/object down

PROTOCOL OF THE MOTHER'S COMMUNICATIVE-AFFECTIVE BEHAVIOURS

Kisses, A05

The mother kisses the baby's face or body. Sometimes this is organised in a rhythmical pattern.

Physical contact

Arm/hand left F01, right F02

When the mother is in contact with the baby's arms, hands or fingers

Leg/foot left F04, right F05

When the mother is in contact with baby's legs or feet.

Body, F07

The mother might be in contact with the baby's body because she holds him/her or because she touches him/her. Body is taken to mean, belly, trunk, back and so on.

Face/head, F08

The contact might be with the baby's face when touching in a caressing movement, or the head holding it.

Face-to-face contact, F10

This is when the mother touches the baby's face with her own face, usually when she holds the baby.

Hold, F09

This is used when the mother dances, or she sits and has the baby on her lap or so on.

Smiling, E00

The mother's mouth makes a smile, very easy to read.

PROTOCOL OF THE INFANT'S PHYSICAL BEHAVIOURS

Head movement

Head shaking, b08

Cyclical head movement: left-right-left or vice versa

Head nodding, b09

Cyclical head movement: up-down-up or vice versa

Head up, b03

Single head gesture up

Head down, b04

Single head gesture down

Head side, b05

Single head gesture side

Head forward, b10

Single head gesture moves forward to the baby

Head backwards, b11

Single head gesture moves backwards from the baby

Body movements

Bouncing body, b00

Cycle of the body: up-down-up or vice versa. Sometimes this is related to the baby's legs movements.

Rocking body, b01

Cycle of the body: backwards-forward-backwards or vice versa.

Twisting body, b02

Cycle of the body: left-right-left or vice versa. Activity that the baby performed when lying on his/her back.

Body up, b00u

Single body gesture up

Body down, b00d

Single body gesture down

Body side, b02a

Single body gesture sideways

Body forward, b06

Single body gesture forward, it could be a movement towards the mother or just in front of his/her own axis.

Body backwards, b07

Single body gesture backwards, it could be a movement away from the mother or back of his/her own axis.

Arm movements

Bouncing arm, left h00, right h01

Cyclical arm movement: up-down-up or vice versa. This is a cycle very neat and readable, it's also usually very fast.

Circling-waving arm, left h10, right h11

Cyclical arm movement either left-right-left or vice versa, or in circular motion. The cycles of this category are less clear and distinct, because the baby is still unable to control his movements and especially the cycles properly.

Arm up, left c02, right c05

Single arm gesture up

Arm down, left c08, right c11

Single arm gesture down

Arm forward, left c12, right c13

Single arm gesture forward, the baby moves the arm in front of his/her own axis or towards the mother

Arm backwards, left c14, right c15

Single arm gesture backwards, the baby moves the arm backwards either from the mother's or on his/her own axis

Arm side, left h03, right h04

Single arm gesture side.

Leg movements

Kicking, left d00, right d01

Cyclical leg movement: forward-backwards-forward or vice versa. Very neat and quick action, usually less than 1 second, done by the baby when lying or sitting.

Cycling-waving, left d03, right d04

Cyclical leg movement: left-right-left or vice versa, or bend-stretch-bend or vice versa.

Leg up, left i02, right i05

Single leg gesture up.

Leg down, left d02, right d07

Single leg gesture down.

Leg side, left d10, right d11

Single leg gesture sideways.

Leg bends, left d05, right d06

Single leg gesture bending. This happens when the baby lies on his/her back or sits.

Leg stretches, left d08, right d09

Single leg gesture stretching. This happens when the baby lies or sits. He/she will stretch the leg above his/her body or in front his/her body

Play with a toy or object

Circling, t03

Cycle of toy/object movement in circular motion.

Shaking, t04

Cycle of toy/object movement: left-right-left or vice versa

Bouncing, t05

Cycle of toy/object movement: up-down-up or vice versa

Toy/object up, t06

Single toy/object gesture up

Toy/object down, t07

Single toy/object gesture down

Toy/object side, t09

Single toy/object gesture side

PROTOCOL OF THE INFANT'S COMMUNICATIVE-AFFECTIVE BEHAVIOURS

Touching

Touches object/toy, left hand g00, right hand g01; left foot g02, right foot g05

The baby can touch the object/toy with a limb. If it is clear that the contact with the toy/object is accidental, it is discarded.

Holds object/toy, left hand g03, right hand g04

This happens when the baby grasps the toy/object and then he/she holds it

Toy/object in his/her own mouth, t08

The baby might take the toy/object in his/her own mouth

Toy/object in the mother's mouth or face, t10

The baby might touch the mother's mouth or face with the toy/object

Touches mother's body, left hand g16, right hand g17; left foot g19, right foot g20

The baby touches mother's body with his/her own hands and/or feet

Touches mother's mouth or face, left hand g13, right hand g14

The baby touches mother's mouth or face with his/her own hands

Grasps mothers clothes, left hand g21, right hand g22

The baby grasps the mother's clothes, especially when the mother is dancing.

Grasps mothers hand, left hand g40, right hand g41

The baby grasps the mother's hand with his/her own hands

Touches his/her own face-mouth, left hand g07, right hand g08

The baby brings the hand towards his/her face or into his mouth

Touches his/her body or clothes, left hand g10, right hand g11

The baby touches his/her own clothes or body

Touches his/her own hand, left g06, right g09

The baby touches his/her own hands

Grasps his/her own clothes

The baby grasps his/her own clothes, left hand g30, right hand g31

Mouth gestures

Mouth wide open, e02

The baby opens his/her own mouth wide

Protruding tongue, e05

The baby protrudes his/her own tongue, usually with his/her mouth open

Mouth shaped, e07

The baby shapes the mouth in imitation of the mother's movement of the lips while singing

Smiling, e00

Baby's mouth smiling