Paris Ouest Nanterre la Défense

Ecole doctorale 139 : Connaissance, Langage et Modélisation

Time Out of Mind:

The experience of being in time in musical improvisation

Présentée par Rebecca Jane EVANS

Thèse de doctorat dirigée par les professeurs
Maya GRATIER et Michel IMBERTY

Discipline : Psychologie
Spécialité : Psychologie de la musique

Jury:

Maya Gratier – Université Paris Ouest Nanterre La Défense
Michel Imberty – Université Paris Ouest Nanterre La Défense
Nigel Osborne – Edinburgh University, Royaume-Uni
Colwyn Trevarthen – Edinburgh University, Royaume-Uni
Dirk Moelants – Ghent University, Belgique
Lutz Fahrenkrog-Peterson –Humboldt University, Berlin, Allemagne

16 décembre 2011

Abstract:

This dissertation investigates live interaction between jazz musicians with a focus on one of the most fundamental elements in improvisational performance, the seemingly simple act of being in time together. What is behind that powerful, engaging quality of music that comes about when musicians collaborate and coordinate so that they feel that are sharing what they themselves call *good time*? To investigate the musical and psychological underpinnings of *good time*, links were highlighted between both existing ethnographic work on jazz practices and psychological studies of time and timing. The thesis presents three empirical studies. The first study consists in a largely descriptive analysis of freely improvised jazz duet performances, and it aims to describe the emergence of good time between musicians playing together. The second study is a quantitative analysis of jazz rhythm section performance (drums and double-bass) based on an acoustic microanalysis of pulse in 4 versions of a song. The third study comprises 2 experiments on the perception of inter-musician timing by 'naïve' listeners, exploring how musically-untrained subjects experience the sound of being 'in' and 'out of' time in manipulated musical samples.

Together, these studies provide quantitative evidence for temporal negotiation or turn-taking at the pulse level. Additionally they show the fundamental role of narrative development in musical performance evidenced by the spontaneous organisation of musicians' improvisations into well framed episodes that have internal structure. It is also evidenced by the mutual establishment of an expressive trajectory of local tempo development that reflects or interprets the musical piece. Thus, these findings demonstrate that musicians together control their expressive performances at both an immediate pulse level and at an overarching level of narrative. An important outcome of this research is that 'successful' performance (one with good time) involves far greater temporal flexibility than previously established. These observations lead us to define an additional form of timing between musicians which we have called *participatory timing* and which is based on motivated and embodied interpersonal interaction rather than on expressive timing at the level of the individual.

Keywords: time, jazz, participatory timing, pulse, narrative

Résumé :

Ce travail s'attache à étudier l'interaction en direct entre musiciens de jazz, en se focalisant sur un des éléments les plus fondamentaux dans la performance improvisée, l'acte de jouer dans le temps avec un autre. Que se cache-t-il derrière cette qualité engageante de la musique quand des musiciens collaborent et se coordonnent entre eux pour qu'ils aient le sentiment de jouer ensemble *dans le temps* (selon leur propre expression)? Afin d'étudier les fondements musicaux et psychologiques de cette expérience, nous créons des liens entre la recherche ethnographique existante sur les pratiques de jazz et les études psychologiques sur le temps et sur le timing. Cette thèse comprend trois études empiriques. La première étude a cherché à décrire l'émergence de cette expérience du temps partagé dans des performances d'improvisation libre entre deux musiciens de jazz professionnels. La deuxième étude est une analyse quantitative de la performance d'une section rythmique (batteur et contrebassiste), qui a pour base une micro-analyse acoustique de la pulsation dans quatre versions d'une chanson. Dans la troisième étude on s'est intéressé à la façon dont des auditeurs dits 'naïfs' entendent une musique qui est 'dans le temps' ou 'en dehors du temps'. Pour cela nous avons effectué deux études expérimentales sur la perception du timing inter-musicien par des sujets sans éducation musicale formelle, en leur présentant des extraits musicaux manipulés.

Dans leur ensemble ces études fournissent des preuves quantitatives qu'il existe une négociation temporelle dynamique entre les musiciens – un partage de temps – au niveau de la pulsation. De plus, ces résultats ont démontré la place centrale du développement narratif dans la performance musicale. L'influence de la construction est manifestée tant par l'organisation spontanée des improvisations musicales en épisodes structurés que par la mise en place collaborative de trajectoires expressive au niveau du développement du tempo local. Ces trajectoires constituent d'ailleurs une interprétation de l'œuvre musicale. Ainsi, ces résultats montrent que les musiciens maîtrisent ensemble les trajectoires expressives de leurs performances, et ce à la fois au niveau de la pulsation et au niveau de la narrativité. Il découle de ce travail l'idée qu'une performance 'réussie' (caractérisée par un temps partagé) implique beaucoup plus de flexibilité temporelle que ce que les recherches antérieures proposent. Ces observations nous amènent à définir un forme nouvelle de timing entre musiciens, que nous appelons le timing participatif, et qui est fondé sur l'interaction interpersonnelle motivée et incarnée plutôt que sur les processus individuels de timing expressif.

Mots-clés : temps, jazz, timing participatif, narrativité, pulsation

ACKNOWLEDGEMENTS / REMERCIEMENTS

Maya Gratier

For being an inexhaustible resource of expertise, guidance, patience and support

Michel Imberty

Pour la musicalité de vos narratives, et m'avoir inspiré une curiosité dans le monde de la pensée Française

Colwyn Trevarthen

For inspiring me to explore a subject that I now love

Anne, Aurélie & Ksenija

Pour toutes nos conversations sur la nature musicale du monde, et avoir été des psychomuses avec moi

Nicholas Donin, Samuel Goldszmidt & Leigh Smith

Pour votre accueil et votre expertise dans le monde de l'analyse musicale

Misja Fitzgerald Michel & Christophe Lavergne

Pour votre temps et votre musique qui est toujours un plaisir à écouter après 5ans de travail dessus

Horacio

Pour votre soutien et expertise très, très technique

Sabrina, Steph, Tavish & Zoë

For your love and support and having an eye for detail

Lindsay & Rob

For keeping my spirits up in the bittersweet world of the PhD

Mum & Dad, John & Michèle

For supporting my decision to be an eternal student of life

Gwilim

For being at my side all along the way

Table of Contents

Introduction

Knowledge about life is one thing; effective occupation of a place in life, with its dynamic currents passing through your being, is another.
- William James (1902, p. 630).

Humans have a particularly intimate relationship with time as temporality grounds our conception of all physically-embodied thought. Indeed, all experience is either 'in the moment', whether recollecting the past or imagining the future. A sense of time and timing is also the basis for interpersonal relations in the present. In social interaction, individuals come to share time as when we say that two people are *in sync* with each other or that they are on the same *wave-length*. There is a clear coincidence between the physical timing of social interaction and the experiences of emotional intimacy and togetherness.

This dissertation explores the experience of 'being together in time' at both the physical and the psychological level. It is an experience that is referred to in a wide range of contexts. For example, two close friends conversing can usually sense when it is most effective for them to take a conversational turn, and a mother and daughter will uncannily anticipate each other's moves during shared activity. Musicians refer to a similar experience in describing a performance as involving 'good timing', or performers as 'being in sync'. The general aim of this thesis was to describe the experience of being together in time by investigating the collaborative process of music-making. What is behind that powerful, engaging quality of music that comes about when musicians collaborate and coordinate so that they feel that they are playing *good time* together?

Playing *good time* is a term used interchangeably with groove, swing and various other descriptors by jazz musicians (Berliner, 1994; Monson, 1996) and is a concept that will be explored in detail in this thesis. Importantly, achieving good time in musical contexts is often considered as the most essential feature of successful performance (Madison, 2006) and is a central part of the jazz aesthetic (Berliner, 1994). In jazz improvisation, Berliner (1994) describes how musicians' most memorable experiences typically occur "when group members strike a groove together" (p. 388). In this thesis I focus specifically on improvisational jazz practices, and on how they can inform us about creating and negotiating good time together. Not only are jazz musicians highly skilled orchestrators of their own sound and movement in time, we can also learn a lot from their knowledge of what being and playing together in time means to them.

Jazz musicians also frequently describe the *process* by which they find a beat together and settle into the groove. It makes them feel tight musically and close personally, generating a sense of togetherness and intimacy (Monson, 1996). It is perhaps telling that one of the ways of saying that a performance was successful is to say "we were jamming tonight", making reference to simply coming together to play. Musician Don Byron says grooving is "a kind of euphoria that comes from playing good time *with* somebody" (Monson, 1996, p. 68, italics in original). Clearly, the process of learning to play 'in time' together is a practical one, and musicians must play and communicate effectively in order to be understood and responded to by other musicians. But the process is also an aesthetic one, as the collaborative production between musicians holds aesthetic value in itself (Duranti & Burrell, 2004; Gratier, 2008; Monson, 1996). Music is created in time, but the meaning of music is related to the shared experience of time, generated as it is through moment-to-moment acts of perception and interaction (Moran, 2007).

In verbal reports, jazz musicians can be extremely clear and eloquent about the way they play together, but in performance they also work in very intuitive ways (Ashley, 2002). For music listeners and musicologists, groove has often been referred to as a 'certain something' beyond notation that performers add to music to make it swing (Keil, 1994). But groove or good time is not pure musicological mystery reserved for the 'musical few', it is a tangible, palpable experience common to beginner and professional musicians alike. This is what Kühl (2008) terms the 'semantic' aspect of music, as he describes how strong, meaningful reactions in the music listener can be evoked by an auditory stream of structured sound. As an amateur jazz musician myself, I have often wondered how it is possible that some practice sessions seemed to be laden with great moments of feeling in time with one or more of the other players, and some did not. Without making any obvious timing mistakes, sometimes our playing felt as if we simply weren't listening to each other. It is a valued skill to be able to find your own groove and groove together with others, but music certainly does not always have good time, even in a group of talented, well-trained performers (Sawyer, 2003). This implies that part of learning to play successfully involves mastering this skill, but it is not generally the result of direct instruction (Friberg & Sundström, 2002). What is the acoustic nature of this shared and implicit know-how? How do musicians coordinate their individual ideas and purposefully negotiate their joint musical productions with good time?

The audience or music listener, too, is often commenting on groove and timing in a performance. They take pleasure in listening out for and celebrating moments of good timing, and criticizing moments when the musicians are intuitively just not quite *in sync* together. The human ear is naturally listening for something in the physical expression of sound, recognizes this quality as a valuable, aesthetic quality of the music, and interprets this quality as something related to timing. But what is it that makes a musical performance sound coordinated or 'well-timed' to us?

There are two general approaches to studying the experience of shared time. One approach is to explore musical thought and action as embodied social experiences. Playing music together is essentially a social, interpersonal and emotional process involving forms of ritual and creativity that are reflected in the musical sound trace. When musicians and audiences judge the success (or failure) of a performance, their expressions imply both *process* and *collaboration* ("he's really *listening* to the other guy/ it's not *working* tonight"). How do two social individuals create and negotiate musical meaning through embodied and audible exchanges? Understanding the cultural conventions of a particular musical style or genre can only in part contribute to answering this question as musical culture itself is continuously negotiated and adapted by current actors, both performers and listeners, of the culture. Musical culture, in short, is the both the basis and the result of musical interaction. Understanding the dynamics of situated, real-time musical negotiation between improvising performers is crucial for psychologists interested in the social and emotional aspects of music-making and for musicologists interested in the genesis of musical forms, styles and genres.

Another approach is to explore biological aspects of being and acting in time, involving temporal motor control and coordination. Some answers are provided by recent literature in developmental psychology suggesting that young infants are equipped with a perceptual-action system that enables them to participate in well-timed social interaction with others. Playing good time with another person may then be a direct result of our biological history rather than a learned trait of certain musical genres. The theory of Communicative Musicality (Malloch & Trevarthen, 2009) is based on the idea that all humans have a natural impulse to communicate with others using innate mechanisms for adjusting and coordinating with others through sound and body movement. Our ways of being, from the preverbal to the verbal contexts in which we communicate, are perhaps inherently musical. Communicative musicality does not simply borrow terms from the musical realm and ascribe them to aspects of communication; it describes how both communicative exchange and musical expression share common biological and cognitive bases. Acts of playing and sharing time in this way facilitate communication itself by leading to an awareness of others' individual motives, purposes and interests (Schögler, 2003).

Empirical research on communicative musicality has centered on the microanalysis of mother-infant interaction. Several researchers have now demonstrated that the social world of the infant is created through a mutual entrainment of patterned movements with others (Beebe, 1982; Murray and Trevarthen, 1985; Papousek and Papousek, 1981; Stern, 1974; Trevarthen, 1999; Trevarthen and Malloch, 2000). When infants as young as 5 months old hear musical or rhythmic sequences (compared to verbal sequences) they spontaneously engage in rhythmic activity with their bodies, and their rhythmic movements are adjusted to the changing tempi of the music (Condon & Sander, 1974; Zentner & Eerola, 2010). Indeed, being in time is a biological necessity, born out of the need to coordinate our body parts together in order to move and express ourselves as one unified and coherent individual (Trevarthen, 1999).

As infants become adults, movements become highly controlled, skilled and stylized, and in artistic domains we add an aesthetic dimension to the way we move rhythmically in time. The manipulation of movement eventually becomes an art form and in collaborative music-making the timing of musicians' actions is essential for their expressive quality. This is why musical expression and negotiation provide an ideal setting for exploring the experience of being together in time. Composers are forever inventing new forms of temporal experience and feeling which can only be explored and expressed by music itself (Imberty, 2005). Through artistic experimentation we are able to reach new heights of awareness of our perceptual and cognitive processes, and jazz can be thought of as a *tradition* of experimental practice.

This dissertation investigates live interaction between jazz musicians with a focus on one of the most fundamental elements in improvisational performance, the simple act of playing good time together. To this end, it was necessary to create links between both existing ethnographic work on jazz practices and psychological studies of time and timing. In this respect my research maintains an interdisciplinary approach, and both qualitative observation and quantitative analyses have been combined to investigate the temporal co-ordination of sound-in-action between duets of jazz musicians improvising together. The objective was not to analyse music as an audible cultural and social object but rather as a performance process, thus highlighting the importance of collaboration in musical activity. It is hoped that using multiple methods in the exploration of the meanings and feelings involved in *good time* will further contribute to an understanding of general temporal competencies and expressive intentional human coordination.

The first three chapters of this thesis present a review of the current literature concerning interdisciplinary research on timing. The first chapter presents studies of the temporality of human experience, including our corporal limits and timing capabilities in performance as well as our auditory perceptual competencies in listening. The second chapter introduces literature pertaining to ideas of social cognition and interpersonal temporal coordination. The third chapter describes music-making as meaningful social collaboration, presenting literature on culturally-determined musical conventions of time and timing, with a focus on one improvisational idiom that is jazz music.

Chapter four introduces and presents methodological aspects of the three empirical studies that make up the thesis. The first empirical study is presented in Chapter 5 and consists of a largely descriptive analysis of freely improvised jazz duet performances, filmed and annotated by both musicians as well as myself. It is aimed at describing the structure and negotiation of the emergence of moments of good time. The second study, presented in Chapter 6, is a quantitative analysis of jazz rhythm section performance based on an acoustic microanalysis of pulse and a macro-analysis of co-constructed form in 4 versions of a song. The third study (Chapter 7) is a series of experiments on the perception of inter-musician timing by "naïve" listeners, exploring how musically-untrained subjects experience the sound of being 'in' and 'out of' time in manipulated musical samples.

Over the course of this thesis, I will develop the argument that good time needs to be understood as a dynamic process of musical sharing. I will show how moments of good time are used to structure whole musical improvisations and are implicated in the generation of meaningful narratives. My findings also quantitatively illustrate the nature of 'shared control' in musical interaction, that musicians control their expression at both an immediate pulse level and at an over-arching level of narrative, and that 'successful' performance involves far greater temporal flexibility than previously established. Finally, I will show how Keil's (1987) statement that "music, to be personally involving and socially valuable must be *out of time*", holds true even for musically-untrained listeners. Music-makers clearly leave significant sound gaps between them in order to 'say something' to each other and to their audiences in their musical collaborations. And music-listeners, because they are intently involved with anticipating those gaps, hear the musical stories that are being told.

1

The Temporality of Human Experience

"Time is one of the defining properties of our world and so of ourselves."
Mari Riess Jones, 1976, p. 31.

In order to act in and perceive the world around us we must do so 'in time'. Many scholars have argued that time deserves to be put back into our consideration of experience (Jones, 1976; Stern, 2000). Time-based skills are found everywhere in cognitive processes and in physical embodied actions. Consciousness itself depends upon an awareness of different, separable moments and their relation to each other in terms of past, present and future (Fraisse, 1984). The accuracy with which movements are timed in the search for musical groove or *good time* is crucial and this requirement is complicated by the need to coordinate our movements with others in ensembles. In order to investigate the meanings and processes involved when two musicians play well together in time, first there is a need to address the ways in which one musician is able to coordinate and consider his own movements. What does current scholarship inform us about time in thought and the prospective co-ordination and control of time in action?

1 Thinking About Time

Time is the very fabric of living: without time there would be no movement and no life. Defining time has eluded even the greatest of scholars, and yet time is one of those universal concepts whose effects have profound social importance, spanning from economic value (*Time is money*) to existential value (*Life is short*). Temporal information is often considered in one of two respects: either as information about the order of events (before, after) or information about the duration of an event (which is most often conceived of relative to a reference duration – longer than, shorter than). The range of possible temporal durations in our daily lives is vast, ranging from the fraction of a second needed to catch a falling teacup, to 9 months of waiting for a family's child to arrive, to 5 years of working on a PhD. Time is both a technical construct, measured in quantities ranging from nanoseconds to eons and based on the perceived regularities of the physical world, and a social construct having both meaning and symbolic significance.

Recently MacDuff (2006) explored the cultural differences involved in the management and experience of time in everyday social interactions and how these differences might affect the way two individuals negotiate a dispute together. MacDuff (2006) presents a diverse range of examples of everyday time, from the ways in which individuals tend to temporally describe particular societies as being either 'slow'- or 'fast'-paced, to culture-specific generalisations about different conceptions of time (e.g. that 'Westerners' believe that time is a commodity).

Researchers Brislin and Kim (2003) have also investigated some such practical instances of our dealings with time, including the perceived flexibility of time and the pace of time. Under flexibility they note punctuality, clock time versus event time, the overlaps between work and social time, and observe that these distinctions are not typically made at a conscious level (Brislin & Kim, 2003). The pace of time however appears to involve more conscious awareness, encompassing relative patience for waiting, queues and (perceived) delays, the respective importance given to past, present and future, the symbolic or metaphoric value of time, one's degree of comfort with long silences and perceptions about the 'efficient' use of time (Brislin & Kim, 2003). Brislin and Kim's (2003) grouping of the ways humans perceive different aspects of practical time hint at a fundamental difference in the way we conceive of time: that there appears to be both a pre-conscious awareness of time at the pulse level, and a conscious awareness of the shapes of passing time.

One prominent theory of time in scholarly debate describes how time is part of the fundamental structure of the universe: existing as the fourth dimension (after 3-dimensional space) in which events occur in sequence. This conception of time is often referred to as the Newtonian or Realist view after Sir Isaac Newton's work. Others, following in the tradition of Gottfried Leibniz and Immanuel Kant, believe that time is not a true entity existing such that events and objects might move or 'flow' through it, instead it is a purely intellectual concept – a means for humans to conceive of the sequencing and comparison of events. Time (like space) in this respect does not exist in and of itself, but is a product of the way humans represent and order the known world. This thesis takes the view that we are neither stuck in the sequential flow of (Newtonian) time nor that (Kantian) time exists only as a description of the world around us: instead we think time is a real, qualitative, essentially human experience and can be separated into an experienced past, present and future. Here I explore the nuances and fluxes of inner (mindful) and outer (physical) time and attempt to link these to musicians' capabilities and preferences. This work takes great inspiration from the recent writings of Colwyn Trevarthen (2009) and Nigel Osborne (2009), and their detailed descriptions of a chronobiology of musical rhythm, which encourages direct engagement between mainstream scholarship on inner body rhythms and musicological work.

1.1 Time governs all mammalian thought and movement

The circadian clock is one of the specific mechanisms in the brain used to organise and align our physiological activities in time. Although circadian rhythms are endogenous (internally-generated and self-sustaining), they are also adjusted or entrained to the environment by external cues, the primary one of which is daylight, which is why a typical circadian rhythm has a period of 24 hours. This circadian clock is the reason why people who wake at a regular time throughout the working week tend to wake themselves just before their alarm clocks go off in the morning. During the night there are natural fluctuations of different types of sleep (commonly known as different sleep 'stages') that are also thought to be under command of the circadian clock. Sleep stages are assessed by polysomnography in a specialized sleep laboratory, where measurements are taken of cerebral activity using electroencephalography (EEG), eye movements using electrooculography (EOG), and skeletal muscle activity via changes in the skin's surface conductivity using electromyography (EMG). A normal sleep pattern includes five stages of sleep which represent the spectrum from wakefulness to deep sleep and each sleep cycle – moving through each of the stages from light to deep sleep and back again – lasts from 60 to 90 minutes on average (Dahl, 1996).

Circadian rhythmicity is also responsible for general states of wakefulness or alertness that continue throughout the day, and these natural stages of concentration tend to be forgotten in our world of structured and busy work and play. The regulation of sleep, arousal, affect and attention in fact overlap in physiological, neuroanatomical and developmental domains (Dahl, 1996). There are generally two stages of wakefulness used to categorise human day-time activity – a stage of activeness or attentiveness and a stage of inattention or relaxation (Dahl, 1996). An active state is characterised by increased skeletal muscular activity, increased ocular movement, greater respiratory and cardiac rhythm and by small amplitude, high frequency, desynchronized EEG; relaxed states are characterised generally by the opposite pattern of functioning.

Sleep, arousal, affect and attention are closely intertwined in a dynamic regulatory system (Dahl, 1996). On a daily basis, the brain regularly cycles through patterns of higher and lower arousal states. But on a moment-to-moment basis, arousal state is strongly influenced by emotional state, vigilance and attention, such that surges of arousal can arise in response to threat, demand, effort or emotionally salient experiences (Dahl, 1996). In short time frames, aspects of the system that increase arousal dominate, allowing an individual to deal with threats or emotional issues or demands for attention. But over longer intervals the sleep and circadian systems override in order to achieve a balanced physiological status (and early in development the balance is largely skewed towards sleep). These basic rest-activity cycles (BRAC) are one reflection of the way in which time governs many of our physical movements and may conceivably be one influence on the temporal organisation of musical activities. If we physiologically find it difficult to concentrate for more than 90 minutes at a time, then continued listening to a recording or continued musical performance or improvisation for longer than this is quite plausibly an unnatural feat of human activity.

1.2 The conception and control of time

One of the most influential scholars on how humans conceive of time is Fraisse (1984). Many of Fraisse's ideas foreshadow current research of small- and medium-scale temporal properties of human thought and action and the more general field of time perception itself. First, Fraisse (1984) noticed a distinction between two quantitatively and qualitatively different types of rhythm, called '*temps longs*' or long durations (400ms-) and '*temps courts*' or short durations (0-400ms). For long durations, those with 'true' durational value, we are aware or can become aware of the passing of time, but for durations under 400ms there can be no real passage of time, instead we simply count, construct and group these durations together. The duration of around 400ms then becomes a cut-off and was termed the 'indifference interval', under which we cannot be made aware of any time passing, but this does not mean that we cannot experience such durations with any quality, nor differentiate say between a note value of 100ms and 300ms.

Fraisse (1984) then further distinguished between two qualitatively different experiences of time. He separated time spans in which we are able to perceive time – when we consider the duration's limits and all of the events that fill it – and those in which we can only estimate time. He then referred to the boundary between the two as the length of the perceptual 'present', an idea which has its basis in William James' perceptual sense of 'now', who denied the existence of a moment of time feeling like being on a knife's edge (James, 1890). The fixed limit between the perception and the estimation of time has often been defined as between 1 and 3 seconds (Fraisse, 1984; Whittman & Pöppel, 2000).

A further reflection of our consideration of time comes from the way we organise external temporal events. One of the ways we automatically do so is using *grouping* strategies, a concept introduced by the Gestalt psychologists of the early 20th century. In adult perception, temporal grouping is influenced by the duration of silence between two events: two sounds will be grouped together if they are separated by a silent interval of 250ms or less and considered independent if they are separated by 1800ms or more (Fraisse, 1984). Furthermore, in a periodic stream of notes, Fraisse (1984) has shown that we tend to subjectively 'rhythmicise' by grouping sound sequences into imagined units of 2s, 3s and 4s. However, London (2004) suggests that 'subjective metricization' may be a more accurate description because we also subjectively accent one event of each group (we tend to hear, say, **1** 2 3 rather than 1 2 3), a tendency which gives rise to the concept of musical meter. Grouping strategies imply that humans instinctively perceive order and organisation around them, perhaps due to the efficient nature of human cognition and/or perhaps due to the nature of the external world itself. Patterns of auditory and visual information inherent to everyday objects and events are certainly always temporally synchronised (Gibson, 1979).

Another of Fraisse's (1984) affirmations was that temporal perception is intimately linked with movement. This conclusion was met after noticing that we find it easier to synchronise our hand-clapping with regular rather than irregular rhythms, and that even when we spontaneously 'beat time' we tend to do so with a regular, rhythmic beat. Experiments with spontaneous tapping confirmed that participants most often tap with an inter-tap interval ratio of 1:1 – resembling the isochronous or pendular motion of walking legs, swinging arms and breathing lungs (Fraisse, 1984).

Fraisse (1984) observed that nervous system rhythms tend to synchronise together, such that the period of one tends to act as a pacemaker for the others. Biological oscillations are found throughout the human body, over a great range of timescales (walking, breathing, heart rate, etc), and several authors have looked for correlates of different tempi with biological movement. For example, Thaut (2003) explored the way in which at a neurophysiological level the experience of pulse or beat is intimately related to different ranges of timing in the coordination of fine and gross movement. These observations have led to the idea that there may be a more common, underlying timing mechanism which affects not only tempo but heart rate and other motor rhythms (Brown, 1979). In addition, random processes (noise, error) have been cited as the cause of all unaccounted for variation in biological, rhythmical movement, but recent research confirms that this cannot be the case: rather, such variation is the result of those fundamental dynamics which are needed to create the movements themselves (Yamada, 1995).

Humans have a range of kinematic opportunities available to us – thanks to the complex articulation of the limbs and head, born out of our unique upright bipedal posture (Trevarthen, 1999). In order to move effectively and efficiently we must move in such a way as to be sensitive to our surroundings and to our effects on them. This involves being able to prospectively regulate our movements in time, and to anticipate this regulation (Schögler, 2002). In a pioneering series of studies on the *biodynamics* of human movement, Bernstein (1967) demonstrated that central to the control of movement is an ability to be both sensitive to the temporal relationship between sensory events, and to possess a motor plan or image with which to anticipate the final goal. His notion of forward thinking or predictive organisation of actions was developed as an alternative to the behaviourist's stimulus-response paradigm introduced by Watson more than 75 years ago. One of the important implications of the design of the human body is that our movements provide an immediate mode of communication with others, and the predictive process allows for self-awareness, practice and the invention of new ways of moving (Schögler, 2002).

1.3 Timing in the brain

The human brain is naturally competent in the control and execution of thoughts and movements in time, with the capacity for partitioning and quantifying time to at least milliseconds (Eagleman et al., 2005). Furthermore, we know that experience can increase our capacity to estimate its duration (Eagleman et al., 2005): a rally-car driver knows precisely when he needs to brake in order to take a hairpin corner at the fastest speed possible. The duration of time is also heavily influenced by our attentional capacities (Tse et al., 2004), such that a tedious long-haul flight can seem longer when you're waiting desperately to see family and focusing all of your attention on getting there. The same flight can, however, seem shorter with a particularly engaging book, because your attention has been shared between the book and the waiting (*Time flies when you're having fun)*. Because there is no organ dedicated specifically to the perception of time, temporal information must be extracted from sensorial information available from the different sensory organs such as the ears, the eyes and the skin. Concerning the resolution of each of the different sensory modalities, research has informed us that the auditory modality is by far the finest and fastest: the cilial cells of the auditory apparatus transmit a signal in 0.1ms, whereas for example the retinal photoreceptors need between 10 and 50ms (Torre, Ashmore, Lamb & Menini, 1995). The most effective means for perceiving the timing of events around us is therefore to listen.

The fine-grained temporality of music and dance challenges both the methods of investigation into the activities of the nervous system and current theories of how basic mental processes are at work (Turner & Ioannides, 2009). After having worked with many clinical cases of neurological disorder, Sacks argues (2007) that our brains have musical processes deeply embedded in them, essential both for professional musicianship and everyday social communication. Widely-distributed cortical and sub-cortical networks together serve the motor, sensory and cognitive aspects of rhythm processing in the brain (Schlaug, 2001), yet distinct and partially-overlapping neural networks subserve each of the different components of rhythm such as tempo, duration, pattern and meter (Parsons, 2001). Reflective of this budding field of musical neurobiology, a recent special issue of Cortex (2009) edited by Katie Overy and Robert Turner has collated several studies seeking the neural bases of musical rhythm – an exploration of the rhythmic brain.

In this issue, Thaut and colleagues (2009) employed tempo-tracking synchronisation tasks and positron-emission typography (PET) to explore the cerebellum's long-established role in rhythmic processing and coordination. They suggest that rather than being associated with pure time-keeping, the cerebellum's activation is linked to increased rhythmic complexity, novelty and learning. Indeed for most rhythmical tasks, neural networks in the cerebellum are consistently engaged (Molinari, Leggio & Thaut, 2007), but pathology in the cerebellum does not affect the capacity to synchronise rhythmic motor responses to an external auditory rhythm (Molinari et al., 2001). Bengtsson and colleagues (2009) also find support for the cerebellum's role in rhythmic processing using functional magnetic resonance imaging (fMRI) of complex rhythm discrimination tasks. Furthermore, they identify a range of motor and pre-motor regions that are active during passive listening to rhythms, particularly during predictable and metrical sequences. Additionally, basal ganglia regions have been shown to be involved in the detection – and possibly the generation – of a steady beat, through the study of diminished performance on rhythmic discrimination tasks by Parkinson's disease patients (Grahn & Brett, 2009). Finally, for the perception of meter, the vestibular system appears to play a primary role (Trainor, Gao, Lei, Lehtovaara & Harris, 2009).

These studies together contribute to a growing body of research that demonstrates that the neurophysiological bases of rhythm and movement are fundamentally connected and distributed across a wide range of brain regions (Overy & Turner, 2009). In addition, this neurobiological research provides considerable evidence that both intuitive and conscious rhythms of movement recruit the core emotional centres of the brain – including the basal ganglia, the limbic system and the cerebellum (Sacks, 2007).

The study of the neural mechanisms of time perception is generally divided into understanding pulse perception and sensori-motor synchronisation. Thaut's studies (2003) have led him to a systems understanding of control mechanisms in the brain and, more specifically, to a theory that the brain naturally forms temporal patterns in synchrony with 'pulsed' structures – that is, the brain tends to organise auditory events at various levels of timing into felt pulse patterns which function as isochronous temporal templates within a specific period (Thaut, 2003). There are several psychophysical indications of this. The first comes from the demonstration that steady-state coupling of a motor response (a tap) to an external rhythm is achieved rapidly – within 1 to 2 repetitions of the rhythmic stimulus interval (Michon, 1967). Secondly, in a study in which random changes in the frequency and tempo of metronomic sequences were introduced, even those changes below the level of conscious perception were adjusted to by making gradual changes firstly to frequency, then to the period and finally by adjusting the synchronisation between the subject's tap and the onset of sound (Thaut & Miller, 1994). The brain clearly tends to gravitate towards a steady pulse and organises the sounds it hears and experiences in relation to this.

The execution of these control mechanisms was originally thought to be coordinated or timed by one or more internal time-keeping mechanisms and carried out by a memorised motor program, hence the two-component model of isochronous rhythmic tapping (Wing & Kristofferson, 1973). In musical terms this signifies that performances of the same piece at different tempi by the same performer would be equal if they were scaled to the same length, implying 'relational invariance' (Repp, 1994). A related theory is that the timing of individual events in a musical sequence might be controlled by what is known as a 'tempo curve', a continuous function directly derived from the hierarchical structure of the music (Todd, 1985). Following these hypotheses, the tempo curve and some scaling factor together could conceivably predict the timing of sequential events in a musical performance at different tempi.

Conflicting evidence has been obtained regarding these hypotheses. Repp (1994) has claimed that the 'major' (cognitively controlled) temporal and dynamic features of a performance change with respect to tempo, whereas 'minor' features are governed by tempo-independent motoric constraints. Today several authors are continuing their investigation of the control mechanisms involved in time perception and execution (Merker, Madison & Eckerdal, 2009; Repp, 2008; 2010). What is clear is that timing has a strong and immediate governance over all human thought (Sacks, 2007), illustrated by the way we temporally organise events, subjectively experience pulse, and are neurologically primed for sensorimotor synchronisation with external events, including music.

2 Origins of Time in the Mind

What do human, lived experiences of time tell us about time's neuropsychological underpinnings? We have seen that our experience of time is intimately related to movement, both conceptually and neurophysiologically, but we can take this idea further to consider the possibility that movement guides our conception of time. Several authors have developed the idea that the biological oscillations found in the body may *provide the raw material* for the development of engagement in the time scales of human thought (Schögler, 2002). The human conception of rhythm itself must be influenced by the regularities inherent in physical, proprioceptive experience (Zbikowski, 2004). These lines of thought are harmonious with theories of embodied cognition, which argue that experience is dependent on the forms and actions of the body, rather than being a rational construction of the disembodied mind (Moran, 2007). The source and reference of all time that we know are the natural rhythms of the mind, so it is quite conceivable that the origins of the biological 'clock' might be found in the fundamental periodicities of the human organism itself.

Infants are quite capable of hearing and distinguishing various elements of time at a very young age. In the first few months of life they are able to perceive the temporal organisation of an auditory stream (Demany, 1982), at five months of age they are able to detect small changes in a pattern of rhythmic stimuli (Chang & Trehub, 1977) and at six months they are able to discriminate between two different tempi with the accuracy of an adult (Baruch & Drake, 1997). Studies of infants have not only illustrated that we are sensitive to rhythms from an early age, but that we seem to perceive rhythm with our whole body. When infants hear musical or rhythmic sequences (compared to verbal sequences) they spontaneously engage in rhythmic activity with their bodies, and their rhythmic movements are adjusted to the changing tempi of the music (Zentner & Eerola, 2010). In a charming study of 'bouncing babies', Phillips-Silver and Trainor (2005) found that 7-month-olds prefer watching a person dancing with a rhythm to which he was previously 'bounced', rather than watching a person dancing with a rhythm he had simply visually observed. Music perception is clearly an embodied activity from an early age.

Infants are highly sensitive to the temporal organisation of sound at a larger scale (Chang & Trehub, 1977; Thorp & Trehub, 1989). Nazzi, Jusczyk and Johnson (2000) have shown that infants prefer speech that has been organised into phrases with pauses regularly spaced between them, rather than disturbed speech in which pauses were inserted into the middle of phrases. In musical contexts, infants have been found to prefer musical samples with correct rather than modified temporal organisation (with pauses inserted into the middle of phrases), from as early as 4.5 months (Krumhansl & Jusczyk, 1990). Prosodic information can also be a useful indicator of the larger-scale structure of sound. Männel, Neuhaus and Friederici (2007) have recently shown an increase in neural responses in 5-month-old infants to the combination of both a pause and prosodic indications (decreased frequency and intensity) at phrase endings. Adult perception also relies on both prosodic changes and temporal gaps to indicate the end of a phrase: in particular, decreased pitch or frequency along with a lengthening of the final note together constitute a phrase ending in musical examples (Imberty, 1991).

Brain processing is essentially rhythmic (Turner & Pöppel, 1983). In addition, the human ability to 'feel the beat' – the detection of a regular pulse in an auditory signal – is considered a fundamental human trait. Winkler, Haden, Ladinig, Sziller and Honing (2009) have recently shown that newborn infants can detect the beat in music, as evidenced by brain activity (mismatch negativity or MMN) when a downbeat is omitted in a rhythmic sequence of events, in the absence of stress or other distinguishing spectral features. Infants clearly develop expectation for the onset of rhythmic cycles (the downbeat), a result that strongly supports the view that this ability is innate. Even in the case of a severe musical disorder (i.e., congenital amusia), the ability to perceive and move to the beat can be preserved (Dalla-Bella & Peretz, 2003).

There is also strong neurological evidence that synchronisation with a beat holds an important place in human cognition. Firstly, the co-ordination of systems, in which disparate information must be integrated, "requires a neural pulse within which all relevant information is brought together as a whole." (Turner & Pöppel, 1983, p. 281). In the visual system for example, multiple levels of detail (frequency, color, depth) must be synchronised in order to be able to associate the many features of a visual scene. Secondly, specialised brain regions are responsible for entraining to a beat, there are different regions involved when moving to a strong metrical beat compared to moving to a non-metrical beat, and infants detect audiovisual asynchrony between a beat and dancers moving to it (Phillips-Silver & Trainor, 2005). One study has illustrated the importance of temporal synchrony between verbal labels and gestures when infants are charged with the learning of those object-names. When mothers are motivated to teach an infant a new object-label she will temporally synchronise her movement of the object with the pronunciation of its name (Gogate, Bahrick & Watson, 2000). In addition, mothers of young preverbal infants used this technique more often than mothers of early-lexical (9-17-month-olds) and advanced lexical (21-30-month-olds) children, showing that mothers adapt their communication to their child's level of lexical development (Gogate, Bahrick & Watson, 2000).

2.1 The study of mother-infant interaction

In recent years, a large body of research has been dedicated to the analysis of the rhythms of infant-adult coordination. It is now clear that early interactions between mother and infant are more than the sum of their constituent behaviours – the interaction itself has become an object of research in which it is fundamental to understand its dynamic temporal organisation (Delavenne, 2011). Both gestures and vocalisations in early mother infant interactions are organised into hierarchical temporal levels, including episodes of sustained engagement or 'phrases' that attract attention and create expectations (Stern, Beebe, Jaffe & Bennett, 1977). At a smaller-scale level, researchers have shown that conversations between mothers and their 10-week-old infants contain a pulse that works to organise their interaction (Gratier & Devouche, 2011).

But infants are not simply passive partners in the conversation, they also seek out interaction with others around them by intentionally manipulating the timing of their own movements. Infants naturally try to express themselves and communicate with others around them using not only their hands but also the multimodal participation of their bodies in a coordinated and synchronous manner (Condon & Sander, 1974). Condon and Sander's (1974) seminal work demonstrated that from a very early age, infants synchronise their hand and arm movements expressively with the rhythms of an adult's speech, and there are now many filmed examples which document the sheer beauty of such simple acts (see Trevarthen, 1999). It appears that we are biologically programmed to seek out and share multi-modal experiences with others, in synchrony.

At 3.5 months an infant is able to initiate a sequence of interactional patterns when she wants to communicate with her mother (Stern, 1985). Every infant cries out for her parents as one of the multimodal means by which they participate in social exchange, but what is interesting is the way they 'organise' their cries in time. It has been shown that early vocalisations are organised according to the same rules which govern adult speech, including the way we take turns with a conversational partner (Gratier, 2003). The way infants engage with others has been described as 'proto-conversation' – a style of communication which exists before infants are able to form words and sentences (Trevarthen, 1974). Studies of mothers speaking to their young infants have shown that the organisation of their speech rests on an implicit understanding of phrasing (Delavenne, Gratier, Devouche & Apter, 2008). There are clear indicators of ends of phrases such as sudden changes in prosody, including a severe drop in the voice's fundamental frequency and a lengthening of the final word, repetition and variation, and an alternation between action and rest. By 3 months of age, we are able to empirically grasp this conversation reflected in the mutual repetitions and imitations of prosodic contours between mothers and their infants (Gratier & Devouche, 2011).

An additional way of showcasing an infant's sensitivity to and engagement in synchronous interaction is by investigating the extent to which they are disturbed by a loss of synchrony between themselves and their communicative partners. In order to test this, a 'double-television' paradigm was developed by Lynne Murray and Colwyn Trevarthen (1985; 1986). In this paradigm an infant and mother are able to communicate solely through their respective images on two separate TV screens. In the experiments a slight temporal delay was introduced between the filmed and projected images of the mother, to establish whether infants noticed the difference between synchronous (contingent) and out-of-sync (non-contingent) communication. Infants between 6 and 12 weeks of age were clearly perturbed by the delayed versions, in which they displayed more negative emotional expressions and looked significantly less often towards the images of their out-of-sync mothers (Murray & Trevarthen, 1985; 1986).

Recently, Delavenne and colleagues (2008) have investigated the temporal organisation of spontaneous interactions by observing the effects of an ecological disturbance of interaction brought about by maternal psychopathology. They found qualitative differences between the temporal organisation of vocalisations of mothers with Borderline Personality Disorders (BPD) towards their infants and control mothers (Delavenne et al., 2008). The differences observed were not the result of the quantity of a mother's vocalisations, but of their quality, as indicated by the way vocalisations were segmented into phrases and the duration of pauses between them (Delavenne et al., 2008). In BPD mothers, they observed long pauses, most probably experienced as temporal breaks, 'empty moments' or 'moments of solitude', which likely "impede the creation of a shared storyline" (Delavenne et al., 2008, p. 61). Similar changes in expressive timing and interactional synchrony have also been observed in mother-infant dyads who have immigrated compared to dyads observed in their own birth country (Gratier, 2003).

Infants actively engage in rhythmic coordination with their caregivers, and in return, every caregiver instinctively engages in multimodal exchanges with their infants in a temporally-organised manner, evidencing a 'multimodal motherese'. This 'intuitive parenting' (Papousek, 1996; Trehub, 1990) need not be described in any further detail to those who have been parents themselves, but it is important to point out that key to their exchange is a coordinated sharing of time and collaborative shaping of dynamic emotional envelopes (Stern, 1989). Indeed, early interactions between a mother and her infant are organised in a periodic manner, changing between moments of intense interaction or engagement to moments of pause or rest (Brazelton, Koslowski & Main, 1974).

It is thought that the reason why mothers and caregivers instinctively do this is to maintain the infant's attention for as long as possible by keeping the proto-conversation or exchange going (Trevarthen, 1979). When a mother adapts to an infant's rhythmic cycles of attention and inattention, she is implicated in a particularly intimate relationship with her child, listening to and feeling for their emotional needs. In this respect when she adapts to the child she becomes the 'follower', but in another respect, at times when she encourages the child to follow her own communicative initiatives she holds the position of 'leader', being the one leading the temporality of their interaction. In both cases, leading or following the other, mutual and temporal 'tuning-in' (Schutz, 1951) to one another holds a central function in the intimacy of their interactions (Gratier, 2003).

2.2 Communicative Musicality: Musical origins of human cognition

"Our cerebral vitality is fatally and infectiously musical, whether we are musicians or not"
(Schögler & Trevarthen, 2007, p. 159).

As researchers proceed with their investigation of the temporal organisation and dynamics of mother-infant interaction, increasingly, the most pertinent and precise terms of description seem to be those borrowed from the musical domain (Stern, 1985; Trevarthen, 1999). One of the most fundamental elements of early social interaction is our ability to coordinate our behaviours in time, and this temporal coordination has often been described with recourse to rhythm, melody and dynamics. The theory of Communicative Musicality (Malloch, 1999; Trevarthen, 1999; Trevarthen & Malloch, 2002; Malloch & Trevarthen, 2009) proposes the existence of a musical dimension to all human expression and communication: we are born with the instinctive impulse to enter into exchanges with other human beings *through* rhythmic forms, melodic variations and dynamic surges of sound and movement. "The rhythmic impulse of living, moving and communicating is musical, as is the need to 'tell a story' in 'narrative time'" (Schögler & Trevarthen, 2007, p. 157). Rather than being a way of describing different qualities of the acoustic sound, this musicality is a part of our embodied nature, ruling over the entirety of our gestures, postures and speech.

A 'musical' descriptor stemmed from the need to explain the complexity and quality of 'proto-conversational' exchanges between newborn infants and their carers (Bateson, 1979; Trevarthen, 1979). Using microanalytic techniques, several cross-cultural studies now have demonstrated the importance of rhythm and coordinated inter-personal timing in mother-infant exchange (Trehub, 1990; Gratier, 2000). For example, a blind infant's 'performance' with her hands of a song she knows well has been shown to precede her mother's singing by only a fraction of a second (Trevarthen, 1999). Infants and caregivers are essentially motivated to communicate *through* the rhythms and melody of their bodies, attempting to engage in a dynamic flow of messages between them.

The temporal forms of such expression are deeply linked to our emotions. Indeed, all experiences of time are in fact shaped by our emotions, but the emotions that Stern (1989) here alludes to are not those instantaneous emotions such as fear or joy, they constitute the way an emotion comes into being, the emotional development of an individual's experience. He terms these emotions 'vitality contours' (Stern, 1989), referring to dynamics and shape rather than static experience. For example *surging* versus *weakening* are two vitality contours which are not emotions, having no modality, but can be applied to describe the emotive quality of any activity. Vitality contours are often described using terms which relate to movement (*creeping, explosive)*, or are simply explained using the physical movement itself (gesturing with the hand). Such terms can be coupled with the more commonly-expressed emotions (fear for example) such that it is possible to have either a sense of fear which creeps into you or fear which explodes in you. Vitality contours are clearly conceptually different from standard emotions: rather than colouring our lives with interest, they instead essentially shape our way of being in the world.

A second line of reasoning for the existence of such dynamic expression comes from research into human brain activity. Trevarthen and Aitken (1994) have explored the neurological basis of communicative musicality and have proposed a model to describe it. Musicality is the active expression of a system they have described as the 'Intrinsic Motive Formation' (IMF), which develops among cells proliferating the brain in a human embryo (Trevarthen & Aitken, 1994). The system evolves as a neuro-chemical affective coordinator and regulator of human movement and experience (Panksepp, 1998). Within the IMF, the researchers propose an 'Intrinsic Motive Pulse' (IMP) which acts as the core generator of a number of hierarchic, motoric rhythms, allowing us to regulate our movements in time (Trevarthen & Aitken, 1994). Furthermore, links have now been drawn between the emergence of communication and neonatal biological rhythms, which suggest that the organisation and very development of an infant's physiological rhythms may lay the foundations for their capacity to take part in a temporally-matched social dialogue (Feldman, 2006).

The control of all movement then comes from this one coherent and integral system in the brain, which orders separate body parts to move in synchrony so that the resultant movement forms coordinated sequences and coincidences in space and time (Schögler & Trevarthen, 2007). The beat and 'intonation' of movement, which is generated internally, is the same whether it coordinates between our own limbs or whether it is experienced sympathetically through others: "We experience (moving) […] with the exact rhythms and accelerations of the movements themselves" (Schögler & Trevarthen, 2007, p. 158). Because emotions are an intrinsic component of those movements, then "through an immediate appreciation of the efficiency and grace of movement we are able to perceive the activity of others as motivated with emotion" (Schögler, 2002, p. 26).

2.3 The multiple timescales of human thought and movement

From birth we are equipped to enter into meaningful exchanges and conversations with others in time and this exchange can occur at several different levels. The theory of Communicative Musicality has elaborated three interdependent, temporal dimensions with which to describe the exchange: pulse, quality and narrative (Malloch & Trevarthen, 2009), the top level of which (narrative) constitutes a temporal guideline for the lower levels in a malleable yet coherent manner.

The pulse of communication refers to the way we use rhythms in our voices to indicate to communicative partners when the next event will occur. Malloch (1999) measured quantitatively the duration of the pulse in mother-infant exchange as occuring at a period of roughly 1.5-2.0s. Importantly, the pulse organises interactive play but there must be inherent flexibility in order for their interaction to be expressive. Through the study of mothers and their 8-10-week-old infants, Devouche and Gratier (2001) showed that the pairs' exchanges were systematically organised by a constant pulse of around 800ms, however they also found that this pulse was flexible – micro-variation existed on the order of 100-150ms. The authors interpreted this dynamic evolution of the pulse as an important tool for rendering their exchange with expression, a notion that will be revisited in later sections.

A second dimension of musicality is termed 'quality', referring to the way in which humans modulate their voice's timbre and melodic contours to communicate with others. The musical dimension which most closely resembles 'quality' here is the musical phrase (Gratier, 2008), and in a biological domain it can be likened to the temporal windows of different physiological behaviour including cycles of respiration and heart rate (Malloch & Trevarthen, 2009; Trevarthen, 1999; Osborne, 2009). The length of these phrases is between 3 and 5 seconds (Malloch, 1999), which also corresponds to the duration of the psychological present described earlier (Fraisse 1967; Michon, 1967).

Finally, the narrative in communicative exchange refers to the way in which pulse and quality are organised into cyces of shared interest and excitement through time (Malloch & Trevarthen, 2009). Narrative involves the repetition of phrases into series that serve to create tension or waiting, growing from a point of origin to its climax and then its end. However, the narrativity to which we refer is different from the narrativity with which we are familiar, rather than concerning language and story-telling in its strictest sense, narrativity in this sense is considered a fundamental genre that organises the way we think and interact, of which literary narrative is only one form (Gratier & Trevarthen, 2008; Ochs, 1997). The approximate duration of a narrative episode is between 10 and 30 seconds, a temporal window in which one can also find cycles of attention and the verse of a poem (Malloch et Trevarthen, 2009).

These three timescales of our communicative musicality have been incorporated into the multiple levels of temporal thought and action in Nigel Osborne's (2009) table of psychobiological time (p. 548-549). Here, Osborne illustrates in detail many of the possible correlates between our physiology and both banal and creative activities of human making including speech and music, building on previous versions of the tables proposed by Fraisse (1984), Iyer (1998), Todd (1994) and Trevarthen (1999; 2007). In the figure below (Table 1) I have represented only part of Osborne's (2009) table, specifically those columns which refer to our autonomic and cognitive physiology, psychophysical feats, music and emotion. Iyer (1998) mentions importantly that because of the inherent variability in human movement the correlates should be regarded as 'fuzzy categories' with some degree of overlap.

	Band I			Band II			Band III			
	Narrative times of imagination and memory.			Times of conscious action and response in the present moment.			Times of action and response below conscious discrimination.			
	Visceral 'episodic' time: 'disembedded', future or past, thought about.			Active, consciously monitored time. The Immediate Present. 'Declarative', reasoned experience, or recollections.			Pre-conscious intervals. Instantaneous awareness.			
	Minutes and longer	Period in seconds and frequency					Period in milliseconds and frequency			
		30–50 0.02–0.03 Hz	10–25 0.04–0.1 Hz	3–7 0.14–0.3 Hz	0.7–1.5 0.6–1.4 Hz	0.3–0.7 1.4–3 Hz	150–200 5–6 Hz	50–100 10–20 Hz	30–40 25–200 Hz	5–20
	NARRATIVE			PHRASE	RHYTHM					
EEG					DELTA	THETA	ALPHA 8–12 Hz	BETA 12–30 Hz	GAMMA 26–100 Hz	
Autonomic physiology and 'arousal'		γ Wave; para-sympathetic heart and EEG fluctuations	β Wave; thermo-regulatory Mayer waves[1]	α Wave; relaxed breathing	Adult heartbeat	Newborn heartbeat				
Cognitive physiology. ERPs[2]			Attention cycle	'Orienting' and 'Expectancy' waves			N200 'Mismatch' wave	N100 Sensory focus potentials		Brainstem responses
Psycho-physics			Extended present	Subjective present	Single, consciously-controlled action. Short-term memory		Automated finger tapping	'Click-sensitive' oscillators. Internal clock unit	Temporal order threshold	Minimal perceived interval
Music	Extended narrative. Song, ballad to large musical composition.		Musical episode 'narrative'	Phrase, slow gesture	Pulse/beat: *largo* to *andante*	Pulse/beat: *andante* to *presto*	Vibrato, arpeggios, rapid movement	Trills, fast passagework		
Singing	Story, novel, play, drama. Theories, history. All elaborated in texts, scores and media.		Verse	Phrase	Bar	Beat	Tremolo			
Melodic or gestural contours			Timeless, floating	Very slow, sedate	Slow, graceful or ponderous	Controlled; urgent to casual	Fast, bursting, impetuous, thrilling			
Poetry			Stanza	Phrase	Foot	Stressed syllable	Unstressed syllable			
Emotions	Recollected self-sensing emotions; anger and anxiety to peace and joy[3]		Moods. Changes of emotion	Self-regulatory and interpersonal: calm, sad, angry, joyful.			Immediate, urgent protective reactions, intensely expressive in communication			

Table 1: Selected lines from Nigel Osborne's (2009) table of psychobiological correlates of time (p. 548-549).

At the far left there is room to include those periodicities of the body's conduct that correlate to even larger-scale organisation of extended forms and 'extended narratives'. Such periodicities must also relate to our natural cycles of rest and activity (BRAC), which last around 90 minutes (Dahl, 1996). We might here cite the activities that bodies and persons meaningfully create in time for which other people gather to see and hear: plays usually last between 50 and 100 minutes and often have an interlude; music albums typically last around 50-70 minutes; television programmes are generally around 50 minutes long (including commercials); films usually last between 90 and 120 minutes (and previously had an interlude in the middle which many people would rather have back). But to the author's knowledge there has been no systematic collation of these activities and their respective temporal lengths.

In addition, if we are to further understand the ways in which individuals coordinate their timing together at the very immediate level of experience, we also need to investigate those periodicities at the far right of the table. In musical terms these periodicities correlate with grace notes, deviations, asynchronies and microtiming. Such qualities might be said to lie in the approximate frequency range of between 10-60ms (Iyer, 1998) or possibly even broader. The subtle timing of movement can greatly inform us about the meaning of an individual's actions, and humans most probably rely on their perception and display of those subtle aspects in many creative and everyday interactive situations.

Donin's (2004) work on 'signed' listening experiences describes the way in which we direct our attention towards certain parts of the acoustic image. We are in fact capable of listening in several different ways at once, or to keep an ear on only one part of the music that interests us. That part which draws our attention most often is of course the present moment, which has a particular 'weight' in heavily in our attentions (Stern, 2004). What this also reminds us is that we can be quite aware of different aspects of the musical soundscape at once. We can at once be controlling our timing on a smaller moment-to-moment level and be mindful of larger-scale developmental, structural and narrative aspects of timing.

2.4 Dynamic forms of experience

When a mother plays the game of 'I'm-gonna-getcha' with her infant, she knows intuitively that the most important feature she must integrate into her game, is one of timing. Stern often talks about this game (1985, 2000), citing it in particular because it provides insight into the ways in which repetition and variation are used to organise time in interaction. A mother begins by situating the game and saying 'I'm gonna-getcha', then repeats this phrase periodically with a specific beat and rhythm. The infant must then pick up on this rhythm in order to be able to anticipate her next actions: the repetitions serve to orient the infant's experiences, allowing him to perceive and to anticipate the unfolding timing of the game. As the phrase is repeated with longer and longer pauses between repetitions, the tension mounts and the infant knows that there is something to wait for. The penultimate step of this simple game is then introducing some form of variant of the phrase itself – 'gotcha'!

But the infant is not only sensitive to the changed phrase, he is sensitive to *when* it is delivered as the game unfolds before him. Meaning does not primarily come from the referential, linguistic content of the message conveyed, but through the means by which the message is delivered (Stern, 1985). This is the essence of narrative development. Different temporal endings can therefore lead to quite different reactions to them. If 'gotcha' arrives too soon the reaction is one of fear or shock – an essentially disappointing result as the infant has not been able to live-out the suspense of the story. A late 'gotcha' is not particularly satisfying either, and usually corresponds to boredom. But 'gotcha' (with a tickle) at *just* the right moment leads to both excitement and pleasure. The game illustrates succinctly that because infants do not have time to cognitively assimilate the rules of the game, they must find it fun because the rules are already part of their being. These rules involve a shared sense of time, and development of their interactions around a line of dynamic tension, with a departure, a climax, and an ending (Malloch & Trevarthen, 2009). Playing with the feeling-state of an infant is often based on temporal manipulations and violations, and it is hard to say when these sorts of games ever become redundant, even in adult life (where novels, films and the pervasive everyday sharing of narratives take over).

Such a process of shaping time as it unfolds has been likened to that of two improvising musicians (Lee & Schögler, 2009). "To be musical means that we are able to humanly shape the passage of time" (Trevarthen & Malloch, 2002, p.). Both the biologial rhythms of infants and the natural rhythms of the environment exhibit the same succession of periods of heightened activity or tension followed by periods of decreased activity or relaxation (Pouthas, 1996). These patterns of tension and relaxation are in fact a defining characteristic of most musics, structuring them with narrative (Imberty, 2005). Playing musical time with narrative is in essence to delimit temporal sequences from indistinguishable flux and to shape meaning into the constant flow of sound. Thus in some respects, music places time and our ways of experiencing time 'on stage'* (Imberty, 2005, p. 189). *(*"La musique met en scène le temps et nos façons de le ressentir")*

On the other hand, musical affect can only manifest itself through time, as "time is the substance of music" (Imberty, 2003, p. 12). Hanslick (1891) alludes to this when he asks "Which part of the feelings can music express, since it is not their substance, their same subject? It is exclusively their dynamic part" (p. 75). For Michel Imberty (2005), research into musical gestures has led him to describe their expression as being not only the reflection of a simple movement but charged with intentionality. He suggests that "there is a natural capacity, a skill particular to the human species which recognises and translates an internal, subjective mediation of musical forms into gesture, whose creation then – and only then – is modulated by codes, styles and civilizations"* (2005, p. 91). These temporal forms of music are elaborated with purpose in order to draw us into a dynamic tension (Imberty, 2005). To resolve the tension in a musical work there is not only one 'resolution' possible, but many, which depend also on culturally-constructed codes of how to perform and how to perceive a particular musical genre (Meyer, 1956). But most important of all, whatever the resolution might be, is the moment when the resolution occurs (Imberty, 2005; Stern, 1989). **« Il existerait une capacité naturelle, une compétence particulière de l'espèce humaine qui rendrait compte de cette médiation interne et subjective des formes musicales par le geste, dont l'invention serait ensuite – mais ensuite seulement – modulée par les codes, les styles, les civilisations. » (Imberty, 2005, p.91).*

It is not such a far stretch to think about the ways in which Beethoven does with us what mothers do with their infants. Lengthening of the final beat and a decrease in pitch are two common indicators that together determine the end of a phrase (Imberty, 1991). As both infants (Trainor & Adams, 2000) and adults are particularly sensitive to final lengthening and changes in pitch, this indicates that we are especially sensitive to those indicators that guide our understanding of phrasing and narrative. In infant games, all the excitement is played in the interval of time it takes a mother to introduce variation, something that is influenced by the initial rhythms and pace of the game. Gratier (2001; 2003) has shown how mothers introduce variation – small shifts in time – into their dialogues with very young infants, creating a pulse which is dynamic and flexible, around which their games can take place. The resolution must be incorporated into the continuity of the game and means that the infant can distinguish between what is the same and what is different - without interfering with the coherence of the game's proto-narrativity (Imberty, 2005).

2.5 Temporal complicity and tuning-in

In 1951, Schutz pointed to 'mutual tuning-in' as the basis of pre-communicative social relationships, and proof that subjects interact as 'co-performing subjectivities'. From his studies of making music together, he noticed the way in which performers and listeners 'tune-in' to one another, experiencing the same flux of inner time. The means by which both mothers and musicians alike tease the feeling-states of others and shape them into dynamic temporal forms is achieved by tuning-in to their emotions. Both adults and infants are sympathetic rhythmic partners (Trevarthen, 1999), and an emotional tuning-in brings two partners into a special communion, allowing them to share or exchange their ways of being and of feeling in time (Stern, 1989). For example, watching a performed rhythmic action and copying the rhythm of this action, using vocalisations instead of actions, is a way of displaying how one has tuned-in to the timing of another, despite responding in a different modality*. It is not the gesture which has been reproduced – vocalisations and arm gestures require completely different sets of muscular activity – so it is the intention behind the gesture, conveyed through timing, which has been understood and responded to. Infants, too, understand the intention behind the act: it is not the mathematical relationship between successive temporal durations which excites an infant, it is the intentionality and meaning conveyed *through* them.

This is perhaps the first clue as to the means by which two musicians might come together and play 'good time', not only by tuning their instruments to one another, but tuning in their emotions. Emotional tuning is an essential process to the construction of interpersonal and intersubjective bonds with others (Stern, 1989). Imberty (2003) suggests that emotional tuning-in is also an essential element for the 'harmonious complementarity' of different parts of a musical quartet, the success of which guarantees the formal consistency of a composition and the performance musicians create of it. In groups of singers too, Lortat-Jacob (1998) has illustrated the importance of emotional understanding. He described the practice of religious passion songs in Sardinia, whose success depends on every member of the choir communicating and sharing with the others, to the extent that rivalries and enmities can give a poor performance and sometimes even prevent the song from being performed. Singing these passion songs primarily consists of entering into a close relationship with the other: "To sing means to accept to share moments of extraordinary emotional intensity" (Lotat-Jacob, 1998, p.197).

**Interestingly, this is one common technique used by drummers to learn a new rhythmic motif – by sounding out the rhythm vocally.*

3 Timing in Adult Movers and Thinkers

This section describes in further detail the specific abilities and limits in both the perception and production of smaller- (micro) scale timing. A large body of work today exists, the primary contributor of which has been Bruno Repp (see Repp, 2005), whose research has greatly contributed to our understanding of the process of tapping in rhythm and general time production and perception. In order to delimit each of the body's many and subtle temporal skills, the following literature has been divided into two parts. The first part deals with timing at an individual level and the second part explores research on timing in synchrony with another object.

3.1 Part I: Going Solo – Moving and thinking as individuals

Perceiving time at the micro-level

One of the earliest clues to the human experience of 'good timing' comes from an experiment conducted by Wallin (1911), who investigated the experience of pulse, and how it changed dependent on introduced deviations from strict isochrony. When he displaced every 6^{th} note of a series of alternating strong and weak sounds with 570-ms IOIs, he found that listeners believed the rhythm to be 'excellent' when the displacement was around 6%, 'good' when it was 8%, 'medium' when it was 12%, 'jerky' at 15% and 'disrupted' at 17% (Wallin, 1911, p.107 and Table VI, p.125). Later on, the ability to detect single deviations from isochrony was studied in a variety of tasks (e.g., Fraisse, 1967), the threshold for which has now been generally accepted at around 6% (Friberg & Sundberg, 1995). However, Madison & Merker (2002) wanted to explore a more ecologically-relevant context by investigating the extent to which the subjective experience of pulse *tolerates* deviations from isochrony. Mean thresholds for detecting irregularity when recurrent deviations were introduced were found to be 3.52%, but the mean threshold for thinking and attributing 'pulse' was over twice as large – 8.59%, suggesting that often individuals heard an irregularity in the samples but nevertheless inferred pulse. This led the researchers to conclude that there must be a margin of tolerance for irregularity when experiencing a pulse in a sequence of events (Madison & Merker, 2002).

As all naturally produced sequences comprise a range of deviations from strict isochrony, including human 'isochronous' pulse production (e.g. Madison, 2000), Madison and Merker (2002) argue that "a margin of tolerance for such deviations is necessary for synchronisation to occur" (p. 201). However, in theory, too large a tolerance would cancel its predictive power and therefore be inefficient. In both respects then, this margin of tolerance to deviance seems a natural and necessary component of our timing abilities, encouraging us to perceive pulse in the sounds around us, but restraining us from being too imprecise.

In order to further investigate our pulse perception, Schulze (1978) tested the way in which we synchronise with a periodic input signal. His studies led him to conclude that when we hear a regular rhythmic pulse, rather than matching the intervals one-by-one or by comparing each interval to an internal 'ideal' interval, we *co-perform* this periodic pulse internally (Schulze, 1978). Such internal, synchronized pulse generation is known as 'entrainment' (see further sections), and is the essence of pulse perception, allowing us to tap our feet and beat our hands to music (Iyer, 1998). A related phenomenon to pulse perception is the perception of meter: best described as a 'periodic grouping of perceived pulses', rather than an objective quality of the audio signal itself (Iyer, 1998). Studies of rhythm perception have shown that meter is, at best, an ambiguous if not completely imaginary property of the acoustic signal (Parncutt, 1994). However, because meter is always inferred, it has been suggested that it serves as an internal periodic template that both frames and temporally grounds human perception (Povel, 1977), providing us with a baseline from which we are able to detect musical variations (such as expressive timing).

Listening to streams of acoustic events seems to consistently evoke both subjective pulse and subjective meter, illustrating the way in which we bestow musical qualities upon even the most banal of everyday sounds. Conversely, this is one of the most difficult tasks for a computer: various attempts have been made to develop signal-processing techniques which derive pulse and meter from musical recordings but often they yield highly inconsistent results, especially in jazz (Iyer, 1998).

Humans are naturally able to listen and respond to music with a wide range of periodicities (far more sophisticated than any pulse-predicting machine). Nevertheless we prefer listening to some pulse rates or *tempi* over others. When listening to music, it is more comfortable to tap one's finger (or one's foot) within a particular range – this is often called the 'tactus' (Lerdahl & Jackendoff, 1983). Listeners prefer beats that occur roughly every 600 to 800ms (Moelants, 2003; van Noorden & Moelants, 2006) which is also the range in which listeners are most accurate in their judgments of duration (Fraisse 1984), and the range in which individuals are the most accurate in judging slight differences in tempo (Drake & Botte, 1993). In addition, as the overall timing of events can accelerate and decelerate over phrases and passages as part of the expressive timing of naturalistic performance, people nevertheless perceive a beat in the music (Large & Palmer, 2002). In addition, the perceived beat can be impressively robust when other counterbeats, out-of-phase accents and syncopation are used in musical play. Indeed some musicians, especially drummers, take pleasure in challenging their ability to 'keep the beat' as others around them are playing anything but those rhythms which would accentuate the beat itself.

The possibilities of tempi for specific musical performances are not endless – musicians can only play within a certain range of tempi dependent on the physical constraints of their bodies and instruments. Theoretical considerations for the preferred tempi of individuals have been divided into two general orientations (Brown, 1979). Seashore (1938) and others have suggested that an individual has only one general tempo preference, but Wallin (1911) and others have assumed that each performer has a preferred speed for each of different rhythmic groupings. A musical work certainly can be performed at different speeds by the same and different musicians, which leads Brown (1979) to conclude that tempo preference is "individual, complex and variable" (p. 20). However the tempo deemed 'indifferent', defined as the 'normal' tempo to which others seem subjectively either 'fast' or 'slow', has been found to reside between 600ms and 800ms (Brown, 1979).

Finally, our perceptual micro-timing capacities pale in comparison to the incredible performance of the auditory system in separating two or more auditory streams from a noisy context (the cocktail party effect, Cherry, 1953). In live musical settings, musicians play in different spatial locations, and by using these spatial cues together with timbral and dynamic cues, a drummer, for example, can easily distinguish the sound of the saxophone player to his left from the guitarist on his right, even when the two are playing at *exactly* the same time. (this line of research is referred to as auditory stream segregation) Auditory streaming refers to the separation of a series of rapid and continuous sounds into two or more co-occurring sub-sequences or streams (Jones, 1976), reflective of an attentional process that we use to "automatically organise our auditory environment" (Jones, 1976, p. 326).

Producing time at the micro-level

Humans spontaneously tap at a rate of around 600ms (~100bpm)(Fraisse, 1956), which is very close to the "intrinsic pendular movements of the body" (Clarke, 999, p. 488). The fastest tap humans can produce with one effector (using one finger at a time) is around 100 - 125ms (Repp, 2005). In music, 32ths are (generally) the smallest rhythmic unit of expression in musical notation (half of $1/16^{th}$ or 𝅘𝅥𝅰). Because the average length of a bar or phrase is roughly 3 seconds (Turner, 1983; Wittmann & Pöppel, 1999), we can calculate the approximate length of this minimal rhythmic unit as being 0.1 seconds (3s/32 = 93.75ms), which is just under our fastest tap. If however we introduce a second effector, as is usually the case in skilled musical performance, the task becomes much more comfortable: Riley (1997) has demonstrated that bassists are able to comfortably play 8th notes at 400bpm – at 75ms intervals. Of course, at such fast speeds the timeframe is too short to allow for sensory feedback between two consecutive taps or notes. In musical contexts musicians are clearly also employing motor programs – sets of muscle commands which are assembled before the movement begins (Keele, 1968) – and using the rich contextual cues of the music in order to anticipate their up-coming movements in time.

The variability involved in isochronous serial interval production (ISIP) has been traditionally described as a linear or accelerating function of the distance between the two taps produced – the inter-onset interval (IOI) or inter-tap interval (ITI)(Michon, 1967). In other words, when producing a series of steady taps, humans tend to either remain fairly steady (linear production) or gradually accelerate or decelerate over time. This capability suggests the responsibility of one timing mechanism in the brain. However, recent work has suggested that there may be "qualitative changes in the human processing of temporally distributed events as a function of time" (Madison, 2001, p. 411), which supports the view that the variety of human temporal competencies share common, cross-modal timing processes.

For IOIs between 200ms and 2 seconds, typical standard deviations for finger tapping have been found to correspond to 3-6% of the IOI (Madison, 1998; Michon, 1967; Wing & Kristofferson, 1973). Madison (2001) describes how this variation in the production of steady taps or ISIP is not random, instead random variations can be added to those resultant of two separate functions – *drift* and *negative first-order correlation*. When aiming to produce a steady pulse, a long interval between two taps is more likely to be followed by a shorter interval and vice versa, a phenomenon that has been termed 'negative first-order correlation' (Wing & Kristofferson, 1973). This might be described as a tendency to 'catch up' on our mistakes as they happen in time, or auto-correction. The second component of ISIP variability involves local trends in the mean IOI which have been termed 'drift', a trend often overlooked in tapping literature (Madison, 2001). Drift is the tendency to accelerate or decelerate over time that corresponds to intervals either decreasing or increasing (respectively). Specifically, long IOIs tend to be shortened (a slower-paced tap rate tends to speed up) and short IOIs tend to be lengthened (a faster tap rate tends to slow down), both approaching a so-called 'indifference interval' of around 700ms (Michon, 1967).

In summary, spontaneous tapping always exhibits some variation (3-6% standard deviations) and timing of the intervals becomes increasingly inaccurate with larger IOIs. Secondly, drift is a ubiquitous physical phenomenon (Madison, 2001), and whether we begin faster or slower, we gravitate temporally toward a comfortable speed of around 700ms (~85bpm). This pace falls also in the range of preferred pulse (600-800ms, Moelants, 2003), close to the preferred tapping rate (600ms, Fraisse, 1956), the 'indifferent' tempo (600ms, Brown, 1979) and within accurate duration perception

(600-800ms, Drake & Botte, 1993). This indicates that a universal tempo preference exists around 600-800ms: "an ideal, average or neutral speed of movement with which all others are unconsciously compared" (Brown, 1979). Tapping literature does not suggest any essential differences between musicians and non-musicians in this context – similar tendencies can be seen in trained professionals and novices alike (Madison, 2001).

3.2 Part II: In time with an external time-giver

Sensorimotor synchronisation with metronomic events

Humans (and perhaps all living biological systems) have an innate ability to synchronise between each of their own body parts and stimuli in their environment. Merker and colleagues (2009) consider the origins and motivation of the capacity to entrain to an isochronous stimulus and suggest that this ability is not unique to humans – synchronised animal calls are also performed by many insects, frogs or crabs. They propose that such synchronisation results in an amplification of their call signal, allowing groups of males to attract females which may be on-the-move, giving them a reproductive advantage. The ubiquity of entrainment is certainly today a hotly-debated topic (see Patel, 2008), but the more relevant question for our purposes is: How do living individuals coordinate their various muscle commands in order to synchronise their actions with an external object?

Sensorimotor synchronisation (SMS)* broadly refers to the rhythmic coordinating capabilities involved in human motor control, addressing the intrinsic human error components of the temporal coordination of movement with a predictable external event (Repp, 2005). SMS has now been studied in great detail, over a range of changing tempi, and a concise review of the literature may be found in an article by Bruno Repp (2005). Researchers are currently refining their definitions of the internal processes that enable people to achieve and maintain SMS. To date, research usually involves a subject finger-tapping to a sequence of mechanically-produced auditory stimuli such as a metronome (Hove, Keller & Krumhansl, 2007; Keller & Repp, 2008; Repp, 2005; Semjen, Schulze & Vorberg, 2000; Wing & Kristofferson, 1973).

*Not to be confused with short message service (SMS) – an instant message sent after having tapped a series of commands into an inanimate object.

In SMS tasks with computer-generated stimuli, variability decreases during childhood and adolescence – we become more precise tappers with age – then remains constant in adulthood (Drewing, Li, & Aschersleben, in press). As adults, musically-trained individuals can achieve a standard deviation of asynchronies as small as 2% of the IOI duration (Repp & Penel, 2004), and as low as 0.5% for percussionists (Gérard & Rosenfeld, 1995). With respect to tempo, variability decreases as the IOI decreases (as the tempo accelerates)(Semjen, Schulze, & Vorberg, 2000).

The absolute time frame within which individuals are able to synchronise to an external event has an upper limit of 3-5 seconds (Pöppel & Wittmann, 1999). Pöppel and Wittman (1999) also found that 600ms was the typical time period limit over which movements remain under voluntary control – the lower limit. However Repp (2005) remarks that the smallest (fastest) mean synchronization threshold tends to be 150-200ms, around the maximum frequency at which a finger can move. But when one only has to tap every 2, 3 or 4 taps so that the bio-mechanical constraint of having to tap as fast as you can is removed, the synchronisation threshold lies typically at IOIs of 100–120 ms (Repp, 2005).

It is well established that tapping out-of-phase with a metronomic stimulus is much more difficult than tapping in-phase (Repp, 2005) – again emphasising the natural preference for synchronising with an object. Of course musicians (drummers in particular) practise rigorously to increase their speed and accuracy, often by perceptually dividing a cycle of notes into groups to help the task. This is different from when musicians physically metricise a cycle of notes by accenting some notes and not others (eg. a 12-beat compas in flamenco becomes 1 2 ***3*** 4 5 ***6*** 7 ***8*** 9 ***10*** 11 ***12*** or 3 + 3 + 2 + 2 + 2). Both techniques are used to help with accurate synchronisation.

Some of the earliest studies of SMS (Miyake, 1902; Woodrow, 1932) have noted that we tend to place our taps slightly before the external stimulus by a few tens of milliseconds. This tendency to tap 'early' is termed the 'negative mean asynchrony' (NMA). Interestingly, this tendency has also been found in studies of mother-infant interaction: for example a blind infants' movements (both arms and legs) were shown to lead their mothers' singing voice by $1/3^{rd}$ second (Trevarthen, 1999). This may be an indication that we enjoy being 'in time' with other individuals to such an extent that we utilise all our cognitive resources to anticipate their actions and often end up being a little ahead as a consequence.

There are two additional findings relating to this tendency: NMA decreases with higher IOIs (smaller asynchrony when the tempo accelerates)(Repp, 2005), and there are large individual differences – some individuals exhibit considerable variability and others are very precise (Aschersleben, 2002). However, the NMA is practically nonexistent in highly proficient musicians (Repp, 2005). Furthermore, it has been shown that all individuals can be trained to synchronise with a metronome with almost no asynchrony (Aschersleben, 2003). Musicians might be more efficient in synchronisation because they naturally pay greater attention to different sensory modalities than less-musical individuals (Repp, 2005), or because they are highly trained 'tappers' as a result of intense musical practice.

The tapping literature demonstrates that individuals can coordinate their body parts in order to synchronise to near perfection (~0.5% of the IOI) with a periodic stimulus at a rate as fast as 100ms (~600bpm). In rich musical contexts, with additional harmonic, melodic and dynamic cues to aide our forward anticipation, musicians are capable of playing with perfect synchrony if they so wish. However, in live musical collaboration the objects with which musicians synchronise are in constant motion themselves.

Sensorimotor synchronisation with a variable external time-giver

The majority of musical situations are participatory, involving overt and active engagement in musical activities in a group situation. As such, an inherent component of musical participation involves coordinating in time or temporally entraining to another person's variable activities. The coordination of rhythms between two individuals has been termed 'entrainment' (Clayton et al., 2004), a term originally coined by physicists to describe the mutual phase-locking of two separate oscillators. Entrainment seems to entail the perception of a regular or periodic pulse, inferred from a sequence of (more or less periodic) rhythmic events, and subsequently organising the timing of actions and sounds around this inferred pulse or beat.

In musical contexts, individuals are able to synchronise to a perceived beat when natural accelerations and decelerations are involved as part of the expressive timing of naturalistic performance (Drake, Penel & Bigand, 2000). For example, people naturally and spontaneously synchronise their actions with the rhythms of music, and rhythm can have a significant impact in coordinating and invigorating basic locomotor movement (Sacks, 2007). Physical exercise is often accompanied by music, and athletes even train while listening to specific musical works, as a competitive cyclist illustrates:

> *"One day […] a few bars of the overture to* Orpheus in the Underworld *by Offenbach started playing in my head. This was wonderful – it stimulated my performance, settled my cadence at just the right tempo, and synchronised my physical efforts with my breathing […] My time was a personal best"* (Kinnison, cited in Sacks, 2007, p. 241).

However, it is important to note that we know significantly less about how we synchronise with changing temporal events (Repp, 2005). Almost all previous empirical studies employing changes in a metronome's period have used either step changes (a sudden change to a new tempo) or rectangular changes (sudden change, then abrupt return to the initial tempo)(e.g. Large, Fink & Kelso, 2002). But in a study by Schulze, Cordes and Vorberg (2005), synchronisation with a metronome was investigated using naturalistic, musical accelerandi and ritardandi. Performing gradual tempo changes both gracefully and accurately is a natural component of the ensemble player's skill-set. The researchers found evidence of subjects 'catching up' and 'overcompensating', but within only 2 cycles or events before settling on the goal tempo, and these patterns held for all subjects, despite considerable individual differences found (Schulze, Cordes & Vorberg, 2005).

Importantly, in collaborative ensembles musicians have visual contact with other players, they are able to rehearse parts in which accelerando or ritardando occur, and there are additional musical cues to particular tempo changes and trajectories. This leads to the assumption that, physiologically, humans are able to coordinate their temporal actions in a musical context almost perfectly. However, musicians must collaborate with other living, breathing individuals, in which case one might assume that inter-personal synchronisation – between social individuals – is more difficult a task.

Perceiving asynchronous events

As musical performers are also music listeners, it is equally important to evaluate the extent to which an individual can perceive temporal gaps between events. Evidence for infant perception has been established: infants show surprise at subtle differences in the durations of familiar stimuli with temporal differences as small as 50ms (Pouthas, 1996). In adults, in one of the most widely cited studies of perceptual timing, Hirsh (1959) found that in order to differentiate successive tone onsets in a non-musical context, a minimum of 2ms between tones is needed. Hirsh also established that in order to make accurate judgments of the perceived order of two successive events of different pitch (each with a 500ms duration), the events need to be spaced at least 20ms apart (1959). A subsequent study demonstrated that for two events with the same pitch but with different intensities, events of the same pitch but of different intensity, only 2ms of separation is needed between the two events (Ronken, 1970). It is now safe to say that the ear hears with considerable accuracy, and there only need be 2ms of space between two events, under ideal listening conditions, in order for the perceptual system to register a 'gap'.

3.3 Consideration for spatial acoustics

One final category of constraints, often omitted in studies of the perception and production of time in musical interaction, relates to the complex nature of sounds and their propagation (Naylor, 1992). Sound propagation and reverberation can be a rich source of information for the listener, and such ambient acoustics play an essential role in communicating emotion and pleasure: acoustic engineers strive to avoid their designs in concert halls leading to a 'dead' sound, where music is 'killed' (Levitin, 2006; Sacks, 2007). Effects of ambient acoustics that influence musical timing include the presence and size of an audience, the volume and reverberation period of the space in which the music is delivered, its ambient conditions (condition of the air, temperature..), and characteristics of the musical sounds projected. For example, in order for a melodic line to be clear and audible, if the reverberation time is long, then the tempo or timing of notes would benefit from a delivery slowed down. That is not to say that musicians do not have other means of creating clarity (using the attack of the note or the positioning of their bodies etc). The fact remains that the physical properties of the sound itself, once it has been created and propagated into the air, also contribute to the perception of that sound. Following this, as the velocity of sound is 331 metres per second, a time difference of around 10ms would correspond to a distance of 3.3 metres travelled – which could realistically separate two musicians on a (rather large) stage. However in settings where the musicians' output is being directly captured by microphones (recording studios, some concert situations), and in settings in which the musicians are playing within 3 metres of one another, we can safely say that any measurement of their timing will be a true reflection of the sounds performed.

3.4 Embodiment and Intent

We are highly skilled conductors of our body parts in time, and when we train as musicians, our capacities are further extended. But this might lead to the impression that there is somehow a little homunculus sitting comfortably in the brain and pulling on puppet strings, away from those body parts she is controlling. It is only since the invention of sound recordings that we have been able to listen to music passively through headphones or speakers and thus separate ourselves from its origins in movement. In traditional societies there are numerous situations in which there is no clear-cut distinction between the performer and the audience (Merker, 1999), but for many Westerners unfortunately this only happens during trips to distant cultures and while sitting around open fires. Movement is not simply a component or a means for individuals to create sounds and make music – a performer's actions are an integral part of the identity of the music she creates (Blacking, 1976).

Movement has long been overlooked in the traditional study of music. Meyer (1956), in his exploration of the expressive qualities of music, distinguishes between formalist and expressionist ways of understanding its meaning. The formalist view conceives of meaning as being an intellectual process that depends on an individual's understanding of the harmonic structure of music; the expressionist view (to which he ascribes) confers that something *inherent* in the music conveys emotion, and from this, musical meaning is deducted. Others have followed in this reasoning, suggesting that music is essentially perceived through a body that moves to its rhythms, rather than being perceived through cognitive processes of segmentation, recognition and categorisation (Iyer, 2002). Then in the domain of general cognitive psychology, James Gibson's (1979) studies on ecological visual perception significantly contributed to a distancing from symbolic processing models of perception. Gibson (1979) proposed a model of goal-directed perception through which individuals detect opportunities for action by *affordances* in their environment. The brain is active rather than passive (Turner & Pöppel, 1983), and as sensory processes (perception) and motor processes (action) evolved together, they should be seen as "mutually informative and fundamentally inseparable" (Varela, Thompson & Rosch, 1991, p. 173).

An alternative basis for cognition is given by the embodiment hypothesis, which proposes that object perception should be understood as perceptually-guided action (Iyer, 2002). We learn to explore our environments *through* the multisensory inputs of our bodies, and temporal information from these inputs is matched to the motor image of the body in the sensorimotor loop (Todd, 1999). One of the simplest examples of the reality of this hypothesis comes from the observation that infants who can walk have qualitatively different reactions from non-ambulatory infants to stimuli such as slopes and cliffs (Thelen & Smith, 1994). The capacity to think and reason clearly arises from the sensory-motor system of the brain and body, rather than from a disembodied form of abstract thought (Johnson, 2007; Lakoff & Johnson, 1999).

Embodiment provides a better fit for the study of musical performance than that of mind-as-processor, as the performances are also embodied, situated activities. Music listening and understanding is constructed actively, depending crucially on the physical constraints and enabling of our sensorimotor equipment (Iyer, 2004). In addition, being able to distinguish musical elements (pulse, meter) from a performance is not a perceptual given; it depends on the person's culturally-dependent listening strategies (Iyer, 1998). Neurological studies of music perception also support this idea by demonstrating that even during so-called 'passive' music listening, different areas of the brain involved in motor production also light up (see Janata & Grafton, 2003). It is clear that music is better understood "not as abstract patterns of sound contemplated in immobility, but as a thoroughly embodied activity of human agents" (Cross & Morley, 2009, p. 67). As such, our musical experience may be primarily determined by the way in which the sounds we perceive align with the temporal structures experienced in our moving bodies (Cross & Morley, 2009).

Even in some electronic music genres, whose production requires very little movement, there are still some traces of embodiment. "It is indeed rather telling that today, the most widespread uses of electronic music are in contexts meant for dance; the least humanly embodied music is ironically that which is *most* dependent on our physical engagement with it." (Iyer, 2004, p. 170). Consequently, the choices of musical material and techniques used by electronic music Disc Jockeys (DJs) are significantly influenced by the responses of the audience (Butler, 2006).

In order to leave an acoustic trace of music, there must be physical objects and bodies moving in time, and the dynamic properties of the movements themselves have been related to their emotional content and meaning (Scherer, 1985). To understand musical meaning, scholarship is now also taking note of the process of embodied music-making. There have been a handful of researchers who have combined their studies of music cognition with an awareness of the embodied nature of music, focusing on the action-in-time level of musical behaviour. These studies have explored the role of the body (Davidson, 1993; Davidson & Good, 2002), its gestures in music performance and musical communication (Wanderley, 2002), and in non-dominant cultural settings (Moran, 2007; Stobart & Cross, 2000).

Keil (1995) refers to embodied aspects of music-making in his convincing description of music:

> *"Music is about process, not product; [..]music is not so much about abstract emotions and meanings, reason, cause and effect, logic, but rather about motions, dance, global and*

> *contradictory feelings; it's not about composers bringing forms from on high for mere mortals to realize or approximate, it's about getting down and into the groove, everyone creating socially from the bottom up" (Keil, 1995, p. 1).*

Because music-making is an intersubjective activity, musicians are always aware of a sense of mutual embodiment; this sense brings about the notion of 'shared time' between listeners and performers (Iyer, 2004). The experience of music requires a 'co-performance' together within a shared temporal domain (Schutz, 1967). Much of the pleasure in listening to music comes from sharing in the temporal experience with others, knowing that the musicians are creating and collaborating together in the same time as we are co-performing in the audience. The idea of musical co-performance is perhaps more easily understood in its literal form, in musical dance settings: in such contexts, using rhythmic movements to mark out time 'physicalises' this sense of shared time (Iyer, 2004). Participatory acts such as palmas in flamenco performance, clicking in blues music and clapping at rock concerts each strengthen this idea that a shared, embodied and essentially temporal experience provides the basis for musical meaning.

3.5 Intentional mistakes?

In addition to the embodied nature of music is the ambiguous nature of musical intent. A word's meaning can be specified with some precision – it usually refers to a specific object or state of affairs in the world – but with musical utterances or gestures the meaning behind the musical intent is far more ambiguous. Cross (2001) has described this by suggesting that music, to a much greater degree than language, encompasses a 'floating intentionality' (Cross, 2001). The same musical work can bear quite separate meanings for two different people, for listener and performer, and even for the same person if the music is heard in a different context. It is simply impossible to agree on that to which a musical piece refers other than to itself (Imberty, 2005). Yet because of music's floating intentionality, music-makers and listeners are able to interpret its significances for themselves individually, and in this sense it may be highly advantageous for social groups, at once encouraging participation and allowing for flexibility (Cross & Morley, 2009).

To investigate those small deviations of note duration and placement which constitute a performer's timing, one question that cannot be ignored concerns whether they are intentional or 'mistaken' (Collier & Collier, 1996). For instance, Palmer (1989) observed that pianists will say they accent melodic notes by playing them louder but what actually happens is that they often play the notes earlier – using timing rather than dynamics to accent their notes. Musicians' behaviour in this instance was non-conscious, but intentional, a result consistent with earlier research suggesting that performers are not always aware of whether they achieve rhythmic accents through timing or loudness (Seashore, 1938). In other instances, Palmer (1989) discovered that, by using *rubato* patterns to mark phrase boundaries, musicians in fact performed as they had intended. These observations encourage researchers to not necessarily take a musicians' word for what he believes he is performing, especially in reference to the subtler aspects of musical performance; instead we should take into account both the impressions and direct measurement of the musicians' performances themselves (Collier & Collier, 1996).

4 In summary

Literature concerning the biological rhythms of the mind and body has revealed several important points. At a biological level, although perfect synchrony with a regular beat is challenging, studies have demonstrated that under certain conditions humans can synchronise with a metronome with almost no error (Aschersleben, 2003). However, it is not a natural behaviour to tap perfectly in time with a metronome, as this task is shown to be 'perfected' only after extended practice. When subjects are free to produce their own rhythmic pulse – when the metronome is removed – they demonstrate spontaneous variation (Semjen, Vorberg and Schulze, 2000). Similarly, some animals can entrain to an isochronous pulse (Merker, 1999); but even they produce variation in their beat. For example male fireflies emit sounds with a common time frame, but adjust them to be slightly out of time or different from the beat of their sexual competitors (Greenfield & Roizen, 1993). In fact all physiological rhythms display fluctuations, and it may be that these 'chaotic dynamics' are intrinsic to the normal functioning of the physiological systems (Glass, 2001). For example, despite its seemingly methodical thumping, the heart's natural rhythms are extremely complex. In addition, in healthy individuals heart-rate changes display a complicated clustering pattern, but in individuals with heart failure the rhythmic patterns tends to break down and it is suggested that in fact they become 'too regular' (Glass, 2001). There is some indication then that being 'in time' with another individual should incorporate natural variation or fluctuation, and predicting and synchronising with the movements of other 'error'-producing humans must be even more challenging.

From a musical perspective, typical accounts for the ways in which musicians can play 'in' and 'out of' time together make reference to visual, auditory and proprioceptive feedback (Palmer et al., 2009). However, such accounts are not able to explain very real, natural musical interaction contexts. Individuals with auditory and/or visual disabilities are also capable of exceptional musical skill, musicians in studio settings can play without visual contact with one another, often recording separate tracks, and feedback *only* is too slow to account for the fine temporal synchronisation that musicians regularly showcase. Furthermore, when playing along with other musicians, there is no perfectly isochronous beat, no completely objective acoustic stability to listen out for and play with (unless playing along with an electronic recording). In this sense musicians are not entraining to a pulse, rather they spontaneously create a sense of pulse as they coordinate their bodies and intentions with others' movements around them (Schögler, 2002).

As the theory of communicative musicality suggests, "Motivated psychological time is the key to social communication in all animal species" (Schögler, 2002, p. 11). Humans possess an innate ability and motivation to communicate with others in time and this communication is enabled through interpersonal synchronisation – becoming tuned-in to the sense of time of another. In order to achieve synchronisation, interaction partners need to adjust their internal states to each other and accommodate for the natural tendency to be slightly 'out of' time. This capacity for sharing thoughts in time also relies on a common awareness of body-related time and space that affords representation in mimetic form (Donald, 1999). Individuals must construct a shared time space, around a common pulse, with inherent variability, yet this coordination occurs *collaboratively*. Social togetherness – the process of 'getting in sync' with other social individuals – surely must include the moment-to-moment interpersonal negotiation of musical material including the tempo and the beat itself.

2

The Social Foundations of Playing Good Time Together

Unlike paintings and poems that can be written in the absence of another living soul, music is essentially a collective activity. Listening to music on private headphones can be a way of escaping from the outside world, delving into one's own personal musical experience. But most often, pleasure in music comes from being able to share a musical experience with another human being, either by sending a new musical recording to a friend, attending a concert with them, or by making music together. In all societies, a primary function of music is collective and communal – to bring and bind people together (Blacking, 1976; Storr, 1992).

Mainstream scholarship has traditionally focused on the ways in which one musician conceives of and performs his music – the way an individual conveys musical expression and meaning to others. This is due largely to an intellectually-driven separation between the study of communication in relation to individual perception and cognition, and communication in relation to social processes and cultural meaning-making (Moran, 2007). In particular, Chomsky's (1957; 1968) theory of the innate grammatical competencies of individuals, termed 'Universal Grammar', provided the field of linguistics a particular status in academia as The science of communication. Moreover, it is now difficult to even conceive of the fundamental importance of physical presence for communication, in view of the technologies available today which are widening the division further and further between communicative acts and the primordial arrangement of being face-to-face with another individual.

Alongside mainstream musicology, however, the focus of ethnomusicologists has been on the social aspects of music-making. This focus was initiated in part by the established writings of ethnomusicologist John Blacking (1976), who looked to socially involved musical performance and action rather than musical 'works'. This thesis aligns itself with such an approach; communication ought to be conceived of in terms of its Latin origins meaning *communicare* – to share or to 'make common' (Clarke, 2004) – rather than a definition relating to grammars and vocabulary.

One of the results of ethnomusical study is the value placed on experience. Because the research domain is concerned with participative music-making inseparable from social context, musical meaning cannot be examined without acknowledging personal musical experience (Moran, 2007). For this reason, a group level of analysis is needed to explain musicians' emergent performance: focusing on the individual creator would only limit this work. "Music always seems to come from outside us, finds its way into us from 'others', binds us to the world, constructs the major psychic bridge between our 'others' and ourselves." (Keil, n.d.). An individual perspective is still required, however, because the internal representations of a performance held by each member of the ensemble can be vastly different. Concerning the performance of a jazz standard, there are a number of musical elements that all of the ensemble members know and will remember about that performance, such as the key, the approximate tempo and the number of cycles of the theme that were played (see Chapter 3, section 3.4.1). But other musical properties will differ in the minds of each member, including moment-to-moment aesthetic impressions of the process of their collaboration. Accordingly, music is not simply the skilled display of sounds, it involves the coordinated negotiation of individual intentions (Gratier, 2008).

As musical performance is essentially a form of social, pragmatic activity (Blacking, 1976), much of music's affective expression comes from the processes involved in interactive *music-making*. In order to ascertain whether expressive groups were purely a result of their expressive constituent members, Broomhead (2001) performed an impressive large-scale study that brought together 12 highschool madrigal choir groups in order to evaluate their expressive individual and group achievements. The study revealed that there were no significant relationships between the expressive achievements of individuals and the ensemble (Broomhead, 2001), indicating that a musical group's expressive efforts can be, at least in part, due to the dynamic *interaction* between its members.

The previous chapter has summarised some of the temporal processes involved in the ability to think, act and coordinate our actions with other objects in the environment. But we are more than just pendulum clocks interacting mechanically with the world around us: we purposefully interact with the world to convey beauty and grace. Furthermore, as we are fundamentally social beings, the way humans connect and relate their actions with others must be guided in part by social and cultural conventions. We are at once conveying meaning – 'saying something' – and trying to negotiate that something with another thinking individual. The pragmatic approach favoured in this thesis is that music is based on an innate, human propensity, which requires an understanding of the musical capacities of individuals, but also an understanding of the social frameworks in which these capacities have been nurtured. This chapter then enquires about both culture-specific and general social rules that guide the manner in which two musicians might collaborate, communicate and play well in time together.

1 Interpersonal Timing and Social Meaning

1.1 Saying something – conveying meaning to others through time

Consider the awkward 'dance' of head movements of two people as they negotiate the side of the cheek on which to formally kiss each other in a traditional French greeting. This is essentially based on the *timing* of our interactions, as our movements provide an immediate mode of communication in time with others (Lee, 1998). People instinctively communicate through the skillful manipulation of time every day: the difference between saying *"I'll help with the dishes"* rapidly, and saying the same phrase very slowly, conveys crucial information about the intentions of the person offering their help. We are also highly sensitive to and perceptive of the temporal dynamics of others' movements and naturally make an interpretation of their meaning. In conversation, if one person hesitates while trying to recall a word, the flow of speech is noticeably, perceptibly changed. Temporal coordination – sensing higher-order periodicities of sound sequences and adapting to them – is simply essential for effective communication (Schögler, 2002), and when it breaks down, understanding and cooperation between partners is seriously hampered.

Without the exchange of words, individuals are also perceiving and making inferences about the timing of others' movements, of which there are numerous examples. Empirically it has been shown that simply by watching a point-light display of an individual's bodily rhythms, footsteps can be correctly interpreted as conveying emotions (de Gelder, 2006), and people can even successfully deduce the gender of another person (Runeson & Frykholm, 1983). Thus from the kinematics of another's movements, viewers are able to apprehend something of the intentions behind their motor acts – their intended expression – via the perceived 'motion' of the signal. These empirical discoveries began after Ray Birdwhistell's (1952) first inquiry of body movement or *kinesics*. Sparked by the observation that verbal utterances were not necessarily dominant in interpersonal communication, Birdwhistell (1952) instead studied the use of body movement for communication by seeking patterns of facial expression and gesture. Others, using microanalytical studies to investigate intentionality and motivation, found that eye contact and mutual gaze in particular are two important means for communication, and intimately related to attention (Argyle, 1976). More specifically still, Ekman (1992) found that it is the timing of those facial actions – the length of a gaze – which is paramount for communicating and conveying meaning. There has even been the recent advent of a field of research named *Chronemics* whose subject of study is temporal communication in everyday situations, including the way people organise and react to time (Walther & Tidwell, 1995).

1.2 How conversation – 'saying something' – is reflective of innate timing

There can be many and varied situations that exemplify the use of timing in social activity to communicate or 'say something' to others. This next section, however, addresses the ways in which the dynamics of a spoken conversation are also reflective of innate timing. The way an individual times his response to another's question, expressing either agreement or disagreement, is surely comparable to the way a musician can express himself, whether he agrees or not with another individual's musical statement *through* the timing of his movements.

Both affective and pragmatic meaning are conveyed through the voice (Delavenne, Gratier, Devouche & Apter, 2008), the prosody or intonations and rhythms of which are constantly being regulated using subtle inflections in order to communicate with others, both verbally and nonverbally (Juslin & Laukka, 2003; Trevarthen & Gratier, 2005). Conversation Analysis (CA) was one of the first instances of empirical research into the timing of social interaction, examining the ways in which individuals design and implement language in its most practical sense to maintain the smooth flow of conversation. Conversation analysts develop elaborate transcripts of various subtle non-verbal details including people's eye gaze, body posture, turn-taking, intonation and pauses as well as their verbal utterances. One of the founding instigators of research into the analysis of conversation is sociologist Emmanuel Schegloff (1989), who recorded and segmented people's talk in everyday contexts in order to understand the structure of language and its links with social relationships. In particular, he investigated the notion of turn-taking acts by which individuals managed their interaction, and 'repair' as a way of resolving ambiguities or misunderstanding (Schegloff, 1989). The study of non-verbal means for inter-agent communication have been explored recently by Clark (2004), who detailed extensively those communicative acts that are needed in the actual production of language in his work titled the "*pragmatics of language performance*". Clark (2004) has illustrated how people use a variety of communicative acts, both verbal (um, ah) and nonverbal (gestures, postures), when they spontaneously converse, in order to coordinate activities they are doing jointly.

While conversation analysis explores an individual's speech acts according to aspects of the speech's function, Discourse Analysis, a broader term encompassing both conversation analysis and language structure, deals with boundaries to elements of speech in accordance with hypothetical sentences (Moran, 2007). Importantly, however, neither conversation analysis nor discourse analysis deals directly with the *timing* of both verbal and non-verbal action – the way in which conversation is acted-out in time (Moran, 2007). Importantly, speaking a language with native fluency not only involves mastering specific vocabulary and grammar, but also mastering of the patterns of timing and accentuation. Implicit knowledge of the sonic and rhythmic temporal structure of a language is an intrinsic part of a speaker's competence, and failing to acquire native rhythm is an important factor in creating a foreign accent in speech (Chela-Flores, 1994). This important factor is only beginning to receive attention in scholarship.

Conversation is not an exchange of monologues, it is a polyphonic duet: even when only one person is speaking, their conversation is both interactional and collaborative (Falk, 1980). In this sense, everyday conversation can also be considered as a form of creative group performance (Sawyer, 2003). Other researchers, in seeking the origins of cultural cognition and learning, have described language as a derived function rather than as a basic function underpinning others (Tomasello, Carpenter, Cal, Behne & Moll, 2005). For Tomasello and colleagues (2005), language is based on the same underlying cognitive and social skills that enable infants to point to things and show things to other people declaratively and informatively. Instead, for Damasio (1999), it is the sharing of 'simple stories' that is fundamental for human communication, cognition, and consciousness itself, and he offers considerable neurophysiological and empirical evidence to support the idea. The conception of communication as akin to story telling and sharing returns us to the theory of communicative musicality, which proposes that "human mental development begins with anticipation of shared purposes and interests through rhythmic mirroring of expressive movements" (Trevarthen, 2001, p. 97). In order to investigate an exchange of meaning then, we should be primarily concerned with aspects of coordination in interpersonal interaction, that take place below the level of words.

1.3 Negotiating Meaning with Others

If making music in time requires a complex set of individual temporal capacities on the part of the musicians, to be able to perform with *good time* requires an understanding and capacity to work with the temporality of others, which in turn requires intersubjectivity. Intersubjectivity is a term borrowed from phenomenological literature which captures the idea that as social beings, we have both an understanding of the self, and a sympathetic awareness of others (Moran, 2007). But even our experience of self is indisputably social and relational (Gratier, 2000). Intersubjectivity has been described succinctly by Edgar and Sedgwick (2002) as a property that "opens up the middle ground between subjective experience and objective experience" (p. 197).

In musical contexts, the immediate experience of music making is enabled through shared knowledge and action, and importantly, shared representations of time. It is impossible for two individuals to have identical representations of what is going on in the performance and where it is going, yet despite this, they are still able to collectively make it coherent. This is the essence of intersubjectivity: the process of coordinating individual contributions to a joint activity (Sawyer, 2003). Trevarthen's (1999) musical approach to intersubjectivity suggests that our primary conscious awareness is essentially regulated by rhythmic motives (the IMP) and that these rhythms are fundamentally communicative. From birth we are equipped to enter into meaningful exchanges and conversations with others in time, and the musicality of this human moving is innately adapted to be an intersubjective phenomenon, transmitting meaning in the experience of acting in common social experience (Trevarthen, 1999). Interactional behaviour is neither solely engaged with the 'real' or objective environment, nor concerned entirely with self-regulation, it is intersubjective, producing signals in order to evoke responses in other persons (Stern, 1974). Resulting performances are by definition collaborative: creativity does not originate solely in one performer's mind then becoming externalized, instead creativity is found in the group process (Sawyer, 2003).

Recent advances have now explored the neural basis of such shared representations. There is fine-grained temporal interplay between regions involved in motor planning and those involved in thinking about the mental states of others. This has been illustrated by common neural firing patterns between performers and actors, evidence for the putative *mirror neuron system* (pMNS)(Rizzolatti & Craighero, 2004). Mirror neurons illustrate the neurological basis of shared time, the mindful experience of 'walking in another's shoes'. They show us that our actions are not strictly private and individual, they are integrated into a network of shared actions with others (Rizzolatti & Craighero, 2004).

Molnar-Szakacs and Overy (2006) propose that a pMNS could also apply to the realm of music. Because perceiving music involves not only hearing an auditory signal, but also understanding the intentional sequences of expressive motor acts *behind* the signal, the pMNS allows for musical experience to be shared between agent and listener (Molnar-Szakacs & Overy, 2006). More specifically, they propose that "interactions between the [pMNS] and the limbic system may allow the human brain to 'understand' complex patterns of musical signals and provide a neural substrate for the subsequent emotional response" (Overy & Molnar-Szakacs, 2009, p. 490). In other collaborative settings through the study of gesturers and guessers in charades games, pMNS activity in the observer (guesser) has been shown to not only fire, but to *continuously follow* subtle changes in activity over time, of the pMNS of the actor (gesturer)(Schippers, Roebroeck, Renkena, Nanettia & Keysers, 2010). An experience of music then involves the perception of purposeful, intentional and organised sequences of motor acts as being the cause of temporally synchronous auditory information.

Chapter 1 illustrated the ways in which an individual is able to coordinate his actions in time with other objects, whether they are isochronous, predictable events or non-isochronous, variable, moving objects. However, even more remarkable is the way in which an individual coordinates, often spontaneously, his actions with another living, thinking individual. Individuals communicate their intentions and perceive the intentions of others – connecting interpersonally and coming to understand one another – through the coordination of their actions, and temporal aspects of interaction processes play a crucial role in this (De Jaegher, 2006).

In one report, Tickle-Degnen and Rosenthal (1990) demonstrated that the quality of a rapport in two-person interactions alters depending on three interrelated components: (a) mutual attentiveness, (b) positivity and (c) coordination, which are all essential factors of successful rapport-building. Moreover, as relationships develop, the interaction changes from a display of 'rigidly' defined, culturally acceptable and stereotypical behaviour, to diversity and freedom in the way participants communicate to one another. As successful collaborations and friendships emerge, there should be an "increase in communication efficiency and coordination and fewer misunderstandings of communication meaning" (Tickle-Degnen & Rosenthal, 1990, p. 279). Schmidt and Richardson (2008) have also been inquiring into the social level of perception and action, focusing on the process of how these social interactions come to be. They have been dedicated to understanding the array of stabilities that arise in inter-personal coordination through the study of general principles of coordination dynamics that govern intra-personal movements, such as coordinating one's legs to walk together (Schmidt & Richardson, 2008).

2 The Social Foundations of Good Time

2.1 Being in time with sociable others

One of the simplest and most pervasive of social behaviours is the way in which people tend to non-consciously mimic the postures and behaviours of others (Baaren, Chartrand, Maddux, Bouter & Knippenberg, 2003), and often this mimicking can happen at the same time. The way individuals unconsciously mimic the postures, facial expressions, gestures and mannerisms of others has been termed the 'chameleon effect' – referring to the sensorimotor-affective coupling in understanding the emotions of others (Chartrand & Bargh, 1999). As humans are sympathetic to the rhythms of others (Trevarthen, 1999), often coordinating one's actions or behaviours with another is simply irrepressible, as for example when one copies another's yawn unwittingly (Provine, 2005).

In order to study the processes involved in conversational interaction, McFarland (2001) examined respiratory timing measures in two interactional partners, to compare breathing during quiet thought, listening and speech. He found that an individual's breathing pattern while listening appeared to mirror the conversational partner's speech pattern, in both the scripted and spontaneous conversation conditions (McFarland, 2001). Furthermore, his results revealed a close coupling or synchrony between the breathing of conversational partners at turn-taking boundaries (McFarland, 2001). Spontaneous synchrony is now being explored in a number of different contexts, including a charming recent study in which researchers observed synchronous heart-rates in proto-conversational exchanges between mothers and their infants (Feldman, Magori-Cohenc, Galili, Singerb, & Louzounc , 2011).

At a neural level, Stephens, Silbert and Hasson (2010) moved away from treating speech production and perception as independent processes within the boundaries of individual brains, to investigate neural activity in both speakers and listeners during natural verbal communication. They found that a speaker's activity is spatially and temporally coupled with a listener's activity, and the greater the success of communication, the more extensive speaker–listener neural couplings were (Stephens, Silbert & Hasson, 2010). Such tightly-nit coordination was found in several neural regions, including early auditory areas, speech comprehension and production areas, areas associated with the pMNS, and in a collection of extra-linguistic areas known to be typically involved in the processing of semantic and social aspects of story-telling (Stephens, Silbert & Hasson, 2010). Furthermore, the researchers found that on average, when involved in successful communication, a listener's brain activity typically mirrors a speaker's activity with a slight delay (1-3s), but in some areas predictive or anticipatory responses were elicited.

Recent research has demonstrated this phenomenon in a more striking situation still: an individual's cardiac rhythms match those of a relative when he is watching him walking on fire in Spanish fire-walking rituals (Konvalinka et al., 2011). Importantly, this study showed that the effects of synchronised arousal over time were uniquely between active participants and related spectators but not participants and unrelated members of the audience (Konvalinka et al., 2011), likely (and logically) indicating that emotions are involved in the equation. Contagious yawning and laughter, coordinated breathing and synchronised physiological arousal are just a few of the many examples of the power of social effects over human activity, and of the ubiquitous nature of temporal coordination in social interaction.

The coordination of activity in time can be divided into *mimicry* or matching another's behaviour and interactional or interpersonal synchrony – executing movements at the same time together. Importantly, moving in synchrony, unlike behavioral matching, requires anticipating others' behaviours in order to coordinate movement timing (Keller & Repp, 2008). Interpersonal synchrony can occur when individuals execute different actions together, such as the coordinated movements of a rugby team, or with the same actions, such as marching bands or Irish dancing competitors. In conversational exchange, "the generation of vocal signals, gestures of the arms and hands, movements of legs and feet, and postural changes of the whole body links all these movements in precise synchrony or successive sympathetic coordination" (Trevarthen, 1999, p. 176).

2.2 Interactional Synchrony

The term 'interactional synchrony' was first introduced by Condon & Ogston (1966) who studied everyday conversational interaction between speakers and listeners, and observed that the key to successful, interpersonal synchrony lies not in the type of body part which moves in synchrony, but in the rhythm and timing of the movements themselves. For Condon and Ogston (1966), there can be two kinds of synchrony; self synchrony (the relationship between an individual's speech patterns and body movements) and interactional synchrony – the relationship between a listener's body and a speaker's voice. Both self-synchrony and interactional synchrony have also been observed in mother-infant engagements, described in a celebrated publication by Condon and Sander (1974). Employing a frame-by-frame analysis of both individuals' body motions and speech sounds, the researchers found that the motions and gestures of newborn infants become naturally entrained to the rhythms of their mother's voice (Condon & Sander, 1974). The ability to match one's movements to another's is clearly a condition of normal interaction with others, and when this capacity is diminished, as it is in dyslexia and autism, communication is compromised (Condon & Ogston, 1966).

Importantly, when two individuals are said to display interactional synchrony, whether in interactions which are verbal, nonverbal (musical) or pre-verbal, their behaviours are not synchronised in the sense of both appearing at the same time, they become synchronised or organised *in time* (Gratier, 2008). The intimate coupling of pre-verbal exchanges between mothers and their very young infants, and their disruption, confirm the importance of innate emotional dynamics and Coordinated Interpersonal Timing (CIT) for regulating shared activities – evidence for "the crucial function of 'sympathetic mirroring' or coordinating the motives of emotions in human intersubjectivity or 'co-consciousness' (Trevarthen, 1999, p. 82). Under this framework, larger physical gestures synchronise with phrases, and smaller gestures such as finger movements synchronise with words or phonemes, reflective of a coordination of the temporal structure of the intentions behind the acts (Trevarthen, 1999). This happens by structuring behaviours together around a common pulse, attending to and moving in sympathy with another's actions – by imitating sympathetically the positioning-in-time and forms of their movement (Schögler, 2002). In this way, shared forms are co-constructed in time-space, hence acts of 'time sharing' – transferring and exchanging inner impulses of behaviour (Schögler, 2002).

The microanalysis of mother-infant exchange reveals just how closely in time adults and infants are coordinated together (Malloch, 1999). Both mothers and infants, when they synchronise their vocalisations to the same beat, demonstrate 'catching up' with the other with a lag of between 120ms and 250ms (Malloch, 1999). For Condon (1986), conversational synchrony is tight but never exact: listeners' body movements tend to match speech patterns to within 50ms, and more specifically, body movements tend lag behind speech in most cases. In musical contexts, the synchronisation between two notes which are 'intended' to be played at the same time by different musicians can be as little as 20ms (Palmer, 1989), however expressive performances are always riddled with variability and deviations (a subject that will be further addressed in Chapter 3). In Chapter 1 the idea was evoked that inter-personal synchronisation might be a more difficult task than synchronising with a predictable, metronomic event, however one fascinating study might imply otherwise. Preschool children have been shown to display higher or tighter interpersonal synchronization accuracy in social contexts than in nonsocial contexts (with a mechanical timekeeper)(Kirschner & Tomasello, 2009). In general social interaction, it may be that coordination with variable synchrony is in fact all the more desirable, as one intriguing study has shown that moderately synchronised social entrainment is experienced more positively than tightly coordinated or uncoordinated engagements (Warner, Malloy, Schneider, Knoth & Wilder, 1987).

Here it is important to mention that there appears to be two, subtly different meanings for the term interactional synchrony. In the first instance, it refers to the process by which two individuals might synchronise – as a process – their actions together in time, or at least the act of moving together with synchronous rhythmic activity. This description has alternatively been referred to as entrainment (Condon, 1977; Iyer, 1998; Merker, Madison & Eckerdal, 2009; Patel, 2008), and sensorimotor synchronisation between individuals (Repp, 2005). In the second instance, and in a broader sense, interactional synchrony refers not to a process but to a quality attributed to or experienced by individuals who are temporally-involved in intense engagement – the state of being mutually attuned or tuned-in to one another (Gratier, 2003; Schutz, 1951). Importantly, the two go hand in hand, as the process of synchronising one's timing with another could lead to a state of synchrony, and vice versa.

What is it about the River Dance that people love? These dancers are truly keeping together in time (McNeill 1995), but there is no improvisation in their movement, and neither is there necessarily intimacy or good feeling between the dancers as they can sometimes be deadly rivals. Is this interactional synchrony, or 'total unison' (Keil, n.d.)? I believe the two are subtly different: it can be wholly impressive to watch others dancing or moving perfectly in time together, but this is different from *getting into* or setting up the synchronous act. When people clap together at a sports match or call for the River Dance encore, people gain unique, earthy pleasure from coming together and doing *something* in time with our unfamiliar neighbours.

2.3 The role of interactional synchrony

Coordinated rhythmic activity is elementary for functional societies, and music certainly plays an important role in organising this coordinated activity (McNeil, 1995), but just what are the uses or roles of such coordinated activity? One of the roles of interactional synchrony involves bonding: according to Benzon (2001), music can facilitate the reordering of close bonds during ritualistic exchange. Along similar lines, other researchers have suggested that interpersonal coordination may have an evolutionarily basis because of its role in social or group cohesion (Brown, 2000; Freeman, 2000b; McNeill, 1995; Malloch & Trevarthen, 2009). Sacks (2007) agrees that social bonding and binding is achieved through rhythm, not only those heard but those internalised identically in all who are present.

> *"Rhythm turns listeners into participants, makes listening active and motoric, and synchronises the brains and minds (and, since emotion is always intertwined with music, the "hearts") of all who participate"* (Sacks, 2007, p. 245).

In every culture there is music with a regular or periodic beat that affords temporal coordination between performers (and invokes synchronised motor responses in listeners) (Patel, 2008), and the universal musical games of young children demonstrate quite simply that such spontaneous periodicities are a perfectly natural and pleasant medium for social communication (Bjorkvold, 1992).

At a conceptual level, interpersonal synchrony can facilitate group awareness. Condon (1986) refers to interactional synchrony as being responsible for creating a space of communicative interaction, and allowing individuals in a group to form a concept of the group-as-such. Benzon (2001) concurs that being aware of one's group as a quasi-abstract entity, and to be attached to the group itself comes from the simple act of synchronising together, reflected by the sound of 50,000 voices together cheering for a rugby team, indistinguishable from one another.

In Chapter 1 (section 1.2) I have outlined the theory of Communicative Musicality, and with it, its arguments for the biological basis of interactional synchrony (Malloch & Trevarthen, 2009). Essentially, temporal coordination or mutual 'tuning-in' (Schutz, 1951) between infants and their caregivers holds a central function in the intimacy of their relations (Gratier, 2003); infants display a form of synchronisation with their parents when they are just one day old (Trevarthen, 1979). Indeed the very organisation and development of an infant's physiological rhythms may lay the foundations for their capacity to take part in a temporally-matched social dialogue (Feldman, 2006). Many studies have now documented the way infants engage in rhythmically-coordinated interpersonal activities (Condon & Sander, 1974; Delavenne et al., 2008; Gratier, 2003; Gratier & Devouche, 2011; Murray & Trevarthen, 1985; 1986; Stern, 1985; Trevarthen, 1999). Consequently, a rupture of this coordination – failing to synchronise with others – has been suggested as the basis for some social disorders including autism and schizophrenia (Scheflen, 1963).

Malloch and Trevarthen (2009) have convincingly argued that the musical, rhythmic nature of interaction and communication is far from being a superfluous addition to its function, it is its basis, and new lines of questioning are now beginning to surface in light of this. In one recent and unique study, Hove and Risen (2009) empirically investigated the question of whether interpersonal synchrony affects affiliation between individuals using a finger tapping study, effectively exploring sensorimotor synchronisation (SMS) in interpersonal contexts. Participants had to match their finger movements with a visual (moving) metronome, while an experimenter either tapped to another metronome synchronous to the participant's one, or tapped to a metronome that was asynchronous to the participant's, or did not tap (Hove & Risen, 2009). It was shown that the affinitive effects were unique to interpersonal synchrony, as tapping in synchrony with an inanimate object (electronic metronome) and simply having the experimenter sitting next to them did not elicit the same changes in likeability ratings (Hove & Risen, 2009). Furthermore, the degree of synchrony predicted participants' subsequent affiliation ratings of the experimenter (high likability ratings correlated with small mean asynchronies).

2.4 Creating a space for communication

An additional role of interpersonal synchrony is one of a negotiated rhythmic *framework* (Gratier, 2007). The term 'frame' has been used extensively by Goffman (1974), who investigated the non-verbal management of an individual's interaction with others around him. For Goffman (1974), framing infers "principles of organisation which govern events – at least social ones – and our subjective involvement in them" (Goffman, 1974, p. 10-11). 'Framing' refers to the process of delimiting spaces or zones within which interactive participants, in both conversational and musical settings, can situate and anticipate events (Gratier, 2008). There are in fact multiple framing devices on which participants in social interaction rely, in order to form predictions of communicative events to come (Goffman, 1974). But the sense of framing which interests us here is a temporal framing which delimits relatively predictable boundaries of groups of events in time. Importantly, however, negotiated time frames are flexible and contrasted with the image of a rigid structure, as they must be adjusted to suit moment-to-moment communicative needs (Gratier, 2008).

Within these temporal frameworks, the content of communication and interaction can be established or grounded: in order for individuals to grasp what others mean, they must have some common background or common ground from which to draw their inferences. 'Common ground' generally refers to mutual knowledge, beliefs and assumptions which are continually being updated in social interaction through displays of mutual understanding, the process of which is referred to as 'grounding' (Clark & Brennan, 1991). Importantly, this does not imply a static stock of knowledge: there must be a degree of variability for the knowledge to be shared. Common ground is continually being updated, and it is precisely this continual process of updating shared knowledge which is meant by 'grounding' (Clark & Brennan, 1991).

There are several conversational grounding devices that have been documented by Clark and Brennan (1991) – ways of displaying an individual's anticipation of common ground. These include acknowledgement (head-nod, verbal confirmation), a relevant next turn (the coherence of the speaker's response), constant and regulated mutual attention, anticipation or utterance completion (completing the other speaker's sentence), and repetition, which can serve as either confirmation or a desire for confirmation. Repetition in conversation in fact serves a number of functions, including interpersonal and aesthetic ones (Tannen, 1989), as it can also consolidate meaning, add to a conversation's cohesion, or add to it's fluency – giving it 'rhythmic flow' (Gratier, 2008). Gratier (2008), however, argues that the fundamental processes involved in such communicative practices have much in common with those enabling individual musicians to negotiate sound in time. Indeed, musical improvisation is described as essentially built on performers' anticipation of each others' expressions and offering each other opportunities for anticipation (Goodwin, 2002).

2.5 Musical grounding

Gratier's (2008) 'musical grounding' ties grounding theory with improvisatory musical practices, and proposes that negotiation in these practices can also occur at the level of a framework. More specifically, Gratier's (2008) study explores "the interactive processes through which jazz musicians display their awareness of sharing a 'common ground' from which they may explore new material together" (p. 72). The notion of a frame and its importance in musical expression has been addressed a number of times in improvisational musical settings (Berliner, 1994; Monson, 1996; Walker, 1994). In flamenco for example, the spontaneity of performance and 'osmosis' among artists is said to be only possible due to the existence of both knowledge of flamenco practices and a restrictive framework (Flores, 2010).

One of the main features of musical grounding theory purports that timing is a natural process of grounding that supports collaborative expressing (Gratier, 2008). This implies that expressive timing and other temporal subtleties at both pulse- and form- levels are part of musicians' common knowledge or common ground, derived from the culture and idiom of jazz performance. Several musical indices of grounding, including those employed at the pulse level, have been documented extensively in Gratier's (2008) work, which serves as a detailed record of the social ways in which musical players share meaning. These include repetition and imitation, mirroring, matching and punctuating each other's melodic and rhythmic ideas, and sometimes completing them.

Synchronisation is also mentioned in Gratier's (2008) work as referring to musicians who play the same thing at the same time, implying that both musicians know the sequence ahead of time and share knowledge of its referential nature. She then elaborates on the functioning of musical grounding devices in a broader sense, and refers to their role in expressing a biological, yet culturally-loaded, human purpose. Synchrony here plays a vital role. "Musicians seize opportunities for synchrony, as they emerge interactively, because synchrony plays a crucial role in reinforcing a solidarity of purposes" (Gratier, 2008, p. 100).

3 Collaborative Practices and Social Functioning

3.1 Children's improvisation groups

Burnard's (2002) study of children's musical improvisation groups has hinted at several basic conventions in musical improvisation. In his study, children naturally assumed a particular focus to their improvisations by organising their time together. They achieved this by firstly gaining entry to play or 'getting in' by establishing and aligning with a group beat, secondly they continued involvement by interacting musically with their instrument or with each other, and thirdly they gave explicit cues to stop (Burnard, 2002). In addition, leadership roles were constantly being negotiated and defined, and dependent on the choices made by leaders, "the children learned how to make everything fit together, or coordinate, blend, challenge, exchange, support and attune responses" (Burnard, 2002, p. 167).

Interestingly, in Burnard's (2002) study there were also regular shifts of focus from one player or musical event to another, mediated principally by the nature and presence of leadership. The focal direction varied depending on whether the interaction was "tightly coordinated, where a leader took control by playing a group-beat that functioned as a pulse for the others to 'follow with a rhythm that fitted'", or "where leadership was shared and control passed spontaneously between players in a more loosely coordinated way" (Burnard, 2002, p. 167). Burnard concludes that the children had clearly learned collectively to improvise together and to exceed their individual creative potential, by "negotiating the rules and roles that were played out as the ethics of music-making established both inside and outside the performance event" (Burnard, 2002, p. 167). This study shows how conventions play a crucial role in even the simplest of creative, musical settings.

"Music is a process of inquiry, a path of action, an exploratory,
in-time sonorous construction of the world." (Iyer, 2004, p. 168).

3.2 Skilled joint creativity

In the first instance, Sawyer (2003) sought to describe the tacit and common-sense understandings of jam sessions. For Sawyer (2003), skilled improvised performances including jazz and improvisational theatre are particularly useful examples for the study of creative joint activities, as improvisation exaggerates several of its defining properties, including collaboration, intersubjectivity, empathy and emergence.

An essential feature of improvisational performance is that it involves at least two people, creating together at the same time (Sawyer, 2003). Jazz musicians are often describing their interaction during performance as a conversation, yet unlike conversation, jazz does not involve turn-taking in its strictest sense, in that the musicians are performing continually. Jazz is like a conversation only when it is conceived of as "a jointly-accomplished co-actional process" (Sawyer, 2003, p. 38). When 'striking a groove' together, musicians seek 'complementary' rhythmic activity within the frameworks established collectively, and it is of equal importance that they improvise melodies without shadowing the performances of the others (Seddon, 2005). In other words, improvisers are concerned with achieving "a collective transparency of sound where each part is discernible" (Seddon, 2005, p. 50).

Because of the intersubjective nature of creative joint activities, performers must negotiate their individual representations of where the music is to go, but they are also enacting their own performance. This implies that they are both performing and indirectly negotiating their intersubjectivity at the same time (Sawyer, 2003), coordinating both the content and process of their productions. Importantly, musicians must communicate effectively in order to produce music together but their communication is also a collaborative production that holds aesthetic value in itself, for them and for their audiences (Gratier, 2008; Monson, 1996).

As such, an important part of learning to improvise effectively involves learning to be receptive, and learning to communicate with the group (Berliner, 1994; Monson, 1996). when improvisers do more than respond supportively to their fellow musicians by stimulating new ideas, for Seddon (2005) this involves a "heightened state of empathy" (p. 50). Jazz musicians additionally acquire and develop their improvisation skills by combining personal performance histories with jazz's artistic traditions in the hope of absorbing and exchanging ideas (Berliner, 1994), but further details of jazz's traditions and their application will be discussed in chapter 3 (section 3.5).

In jazz, no single musician is responsible for the flow of a performance, instead it emerges from the musical conversation between musicians. In group creativity and in particular when the group dynamic is said to be 'flowing', the level of the resulting performance can be higher than an individual performer would have been capable of alone (Sawyer, 2003), echoing the work of Broomhead (2001). A practical example of this is to consider the number of musicians who have left their successful groups to explore a solo career which never seemed to take flight. Emergence refers precisely to those situations in which the whole is greater than the sum of its parts, and the global behavior of a group is said to emerge from the interactions among the individual performers (Sawyer, 2003). Because of this unique emergence in creative joint activities, it is quite impossible to predict the flow of performance or direction of the group, even if we have unlimited information about the skills, motivations and mental states of individual performers (Sawyer, 2003). This provides an additional reason for why individual psychology cannot provide a complete explanation of the creative processes in such group contexts, and why it is important to consider the contributions from group dynamics and sociology.

An additional important aspect of creative joint activity involves the presence of an active, collaborating audience. In modern-day concert settings, the audience are typically not allowed to interact with the performers except by applauding at prescribed moments usually at the end of a piece (and in orchestral settings even applauding is limited and highly prescribed). But this social situation is rather unique, in many musical cultures the audience-performer barrier is far less strict (Blacking, 1976). In jazz, as in many other improvisational genres, the audience tends to participate with applauding and verbal appraisal during the performance, especially at moments which are particularly creative or successful. Such an audience interaction can necessitate a relatively knowledgeable audience, indeed at many jazz performers, the majority of audience members can often be themselves musicians of this performance genre (Sawyer, 2003).

Certainly, interacting with the audience can be considered an essential component of the resulting creativity of the musicians (Sawyer, 2003), and certain jazz aficionados believe that 'true jazz' is only when it performed in a club setting with a live audience. Alternatively, some musicians prefer to ignore the audience as much as possible and focus on their own creativity and interactions with fellow band members. This can be coupled with the fact that there can be often relatively naïve audience members, and people who attend concerts principally to socialize and thus treat the music as an "appropriately sophisticated soundtrack to their evening on the town" (Sawyer, 2003, p.71). For these reasons, groups often prepare a performance with respect to the level of sophistication of the audience (Berliner, 1994).

3.3 Interactional coordination in music

One of the defining features of creative musical works and indeed all creative group improvisation is the interactional synchrony between musicians (Sawyer, 2003). Indeed, the ability to enter into a musical exchange relies *primarily* on the skill of temporal coordination (Schögler, 2002). Schutz (1951), in his seminal paper titled *Making Music Together*, describes the process of musical interaction in notated genres, and proposes the term 'mutual tuning-in' as a way of describing the mutual attunement observed between musicians. For Schutz (1951), tuning-in involves a convergence of the fluxes of 'inner time', as performers and listeners become synchronised into a 'vivid present'. In musical contexts performances are often said to 'work' because the performers are "closely attuned to each other" (Sawyer, 2003, p. 37). Musicians are both monitoring their own performance and that of other musicians, and it is crucial to be able to quickly hear and see what other musicians are doing and to acknowledge them, by altering their own ongoing performance.

In classical music settings, interactional synchrony between musicians could understandably be a consequence of having been *led in time* by a conductor or group leader. However, musical groups can achieve synchrony and intersubjectivity even in the absence of a conductor. Malhotra (1981) investigated gestural communication between members of an orchestra, and showed that musicians rarely watch the conductor, in fact 15% of performers report that they *never* look at the conductor. Musicians must be using other means to coordinate their sounds within the ensemble, such as listening to and watching other musicians close-by, and attending to their gestures, facial expressions and bodily movements (Malhotra, 1981). A timpanist's raised eyebrow for example might be used to signal to the 2nd percussionist that he was playing too loudly in a particular section. Often in these genres, however, much of a group's subtle corporal interactions are intentionally down-played and hidden from the audience during a performance (Weeks, 1990).

In western classical, jazz and popular music, studies have shown that eye contact between musicians is both frequent and essential for interpersonal coordination, and even in rehearsals when musicians can talk freely, a predominance of eye-contact is seen over spoken language for communication (Davidson, 1993; Davidson & Good, 2002; Williamon & Davidson, 2002). When Weeks (1990) investigated interactional synchrony in groups performing European orchestral works, he demonstrated the crucial role of interactional synchrony in managing changes in tempo and managing mistakes. Weeks' (1990) analyses revealed that the features of a performance which require the most interactional coordination and effort are the following: the initial tempo of a piece, the rate to slow down to during a ritardando and relative durations of the fermata (an indication on the score that a note should be held for an indeterminate length of time).

The investigation of temporal coordination between two individuals in collaborative and creative musical settings has rarely been approached, but research in the last ten years has begun to uncover some interesting findings (Marsh, Richardson & Schmidt, 2009). One study has shown that it might be in fact easier to synchronise with another person, as adults tend to synchronise more accurately with a human partner than with a recording (Himberg, 2006). More recently still, Kleinspehn-Ammerlahn and colleagues (2011) investigated the development of synchronisation accuracy between partners using drumming dyads, mixing partnerships such that there were adult-only dyads, child-only dyads and adult-child dyads. As one might expect, adult-only drumming partners showed the most accurate interpersonal synchronisation, but the interesting finding was that children improved their synchronisation reliably when paired with older partners (Kleinspehn-Ammerlahn et al., 2011). The concept of interactional synchrony in musical settings will be extended in Chapter 3 (section 3.3.1), but in this next section I will attempt to outline some of the basic frameworks and conventions under which *successful* joint musical expression emerges.

4 Playing Nicely: Rules of Improvisational Etiquette

In the world of jazz, a restrictive list of social conventions and graces exist that are a result of common cultural practices, learned through a process of professional socialisation. One detailed account comes from Becker (2000), who drew similarities between specific conventions in jazz improvisation and the informal, implicit conventions of good social conduct. A fuller account of specific musical conventions will be given in Chapter 3 (section 3.4.1 & section 3.4.2) after musical terms have been clarified; here I will describe some of the general social rules of conduct in jazz that can be applied to a number of interactive, collaborative settings.

When musicians stick to the rules, respecting their fellow players, the music develops a collective direction that characteristically feels larger than if the players had been on their own (Becker, 2000). However, there are serious consequences if a musician is naïve to these conventions, and fails to follow the rules. Becker emotively describes his musical experience on the matter:

> *"If, however, the participants are not courteous to each other that way, do not listen carefully and defer to the developing collective direction, the music just clunks along, each one playing their own tired clichés. If the players are experienced and the clichés professional, the result won't sound bad, although it won't excite anyone either; if those things aren't true, it will be a painful experience"*
> (Becker, 2000, p. 173).

These conventions in jazz, according to Becker (2000), are based on the premise that everyone is equal – jazz is "aggressively egalitarian" (p. 172). As new musicians can come from any social background and must, at some point in their musical development, 'come out of the woodwork', treating everyone in the group as an equal and allowing them to take a turn is a way of discovering and encouraging new talent.

4.1 Who is 'in' and who is 'out'

In making reference to those who stick to the rules and those who don't understand them (or who won't), we should contemplate Becker's (1963) writings on deviance. Becker (1963) originally introduced this work to describe the phenomenon of social *deviants* – those individuals who are considered 'offenders' or 'rule-breakers' of society. There are several important consequences of this work which need to be considered if I am to attempt to describe good timing in a social sense, as 'good timing' can also be thought of as behaviour which conforms to some predefined norm, and 'otherwise' can therefore be considered as deviant from this. Importantly, the definition of what constitutes playing 'good time' must in part be a reflection of the society who has created the rules whose infraction constitutes deviance. "Different groups judge different things to be deviant. This should alert us to the possibility that the person making the judgment of deviance, the process by which that judgment is arrived at, and the situation in which is it made may all be intimately involved in the phenomenon of deviance" (Becker, 1963, p. 4).

When social groups create deviance, they are by definition applying rules to particular individuals and labeling them as 'outsiders' (Becker, 1963). In this sense, as the world of jazz contains its own set of social conventions, we can divide jazz audience members into individuals who are aware of those norms and conventions of the group, and 'outsiders' who are foreign to them. As a consequence, outsiders may perceive a player's timing to be qualitatively different from those who are knowledgeable of those conventions, including the active musicians of that group (those who have created – or are implicitly upholding – the norms themselves). Others have taken up this notion in jazz contexts, agreeing that specific knowledge of collaborative conventions defines the way an audience listens.

> *"When we say that the 'inside' audience has structural competence, we mean that they can recognize basic elements in what is being played as it is being played […] The rest of the listeners – the outside audience – really do not hear or understand […] it may be as meaningful in some way for us to hear an impassioned – but untranslated – speech by the prime minister of Japan"* (Perlman & Greenblatt, 1981, p. 181).

The study of musical conventions in relation to deviance recalls work performed by Csikszentmihalyi (1990; 1997) on creativity. As psychological investigation into creative activities was developing, rather than studying an individual's cognitive representations, motivations and goals, creativity researchers began to focus on the social and cultural contexts in which creative endeavors occur. Csikszentmihalyi (1997) proposed a systems view of creativity, which downplayed the idea that 'creative individuals' exist – people who are effectively creative in all contexts and domains of activity. Instead, he argued that individuals can only be creative in reference to some agreed (cultural) conception of what counts as creative work (Csikszentmihalyi, 1997).

4.2 Social conventions in jazz practices

Perhaps the most obvious of social conventions in jazz is that the leader of the group takes many vital decisions for the organisation of their musical interaction. The leader typically determines the style for the group, and the others are supposed to support and follow along in this decision. Another convention stipulates that every musician in the group must have the opportunity to perform a solo, and in addition, when soloists are taking their turns at improvising, each subsequent improvisation should be roughly the same length as the very first one performed (Becker, 2000). This is proposed as a resolution between two competing tendencies: to play for a shorter period of time would mean that the second musician wasn't as skillful or lacked inspiration, and to play for a longer period of time would mean that he believed he was more skillful or inspired than the first (Becker, 2000). Furthermore, musicians should not unexpectedly surprise or challenge another musician to play something they are not capable of playing, embarrassing them or 'showing them up'.

Other roles in jazz practices, on the other hand, are less discrete than simple leader and follower. There may be one musician who dominates the group, such as the group leader or main soloist, but often there is a certain balance between the statues of one another precisely so that everybody is creating together on the same playing field (Berliner, 1994; Sawyer, 2003). Each of the musicians is allowed (and required) to 'offer' musical ideas to the others, an idea which can then be taken and repeated or transformed into something else (Gratier, 2008). But there is no pause between the presentation of these ideas: the musicians are playing together non-stop. In music the boundaries between self and other are not clear, and can constitute part of what the musicians are in fact negotiating (Duranti & Burrell, 2004).

The musical work is at all times influenced by the interpersonal dynamics of musicians, including during rehearsal and performance (Davidson & Good, 2002). To explore social and musical coordination between young students in a classical string quartet as they prepared for their first recital, Davidson and Good (2002) focused on the roles adopted by each of the musicians. They observed important social interaction between the second violinist – the only male member of the quartet – and the other three female members. Notably, the second violinist often criticised the first violinist on her ability to 'keep time', yet all three women allowed the second violinist 'musical space', making allowances for his weaknesses as a player. This meant that the second violinist was criticising something that he was partly the cause of (Davidson & Good, 2002). This demonstrates that individual musicians bring to the collaborative performance not only their instrumental expertise, but also their particular sensitivities and sensibilities to each other as persons (Gratier, 2008).

At another level still are the morals and identities of individual players (Duranti & Burell, 2004). Friendship, for one, is particularly important in general collaborative settings. When friends work together they are shown to generally increase their sharing of task information, make frequent in-depth and on-task suggestions, and demonstrate increased intersubjectivity (Vygotsky, 1978); quite naturally it is much simpler a task to 'put oneself in the shoes of another' we know well. Similar successful working practices have been explored in children's unstructured musical collaborations (Miell & Macdonald, 2000). When children make music together as friends, their musical creations are then judged of a much higher quality by music school teachers than children who play with unknown others. An explanation for these unique effects of familiarity could come from shared knowledge, facilitating the collaboration of a pair of friends working together, as well as encouraging musical confidence in the musically-inexperienced member of the pair (Miell & Macdonald, 2000).

Certainly, some combinations of individuals work better together than others (Duranti & Burrell, 2004), and this is also the case for certain creative theatre actors, despite their exceptional talents and efforts (Sawyer, 2003). When a particular combination doesn't work well, actor Alan Arkin described "I just felt it wasn't a well-matched group. The four of us weren't on the same wavelength" (Sawyer, 2003, p. 48). For successful collaboration and friendship to emerge, musicians must be able to trust in, care about and respect the musical abilities of the ensemble players (Seddon, 2005). This is especially the case when improvising musicians are taking musical risks: musicians need to know for example that they can rely on others to mark the time cycle if they temporarily lost it themselves (Monson, 1996). Trusting fellow ensemble members exemplifies democratic engagement, not authoritarian control (Becker, 2000), which brings us back to the essence of collaborative music-making.

4.3 Tension and Balance

An additional defining feature of group creativity is its unpredictability: no single person knows, at any given point in the performance, what is going to happen next. Each musical turn takes on a meaning that is determined by the collaborative, emergent process (Sawyer, 2003). There is of course, rather than a duality between fully predictable and unpredictable, a spectrum of possibilities between the two, with more predictable performances being those in which one's actions are limited by the conventions of a genre or situation (Sawyer, 2003). Such unpredictability means that resulting performances have 'combinatorial complexity' (Sawyer, 2003): at each moment in the performance, subsequent actions chosen (a note, rhythm, motif) can lead to very different outcomes, in effect multiplying the range of potential performances that could emerge.

There are several sources of inherent tension in jazz performance, which constitute an important element in the development of the musical performance itself. The standard jazz quartet or quintet exists somewhere in between structure and 'nonstructure', in that it is both a highly developed context and one with ephemeral creativity (Sawyer, 2003). This suggests that musicians are constantly seeking balance between the tendency to perform completely unstructured improvisation and highly reflected and elaborated composition. A related source of tension involves the desire to be coherent with their musical traditions and their group, and the desire to be creative and innovative (Sawyer, 2003). Another involves an inherent competition between the desire to be an individual – to freely express and be remembered for one's individual style or a particular performance – and the desire to work together democratically, limiting one's freedom "for the good of the group" (Sawyer, 2003, p. 50).

4.4 Flow

The experience of making good time together may also be related to the experience of 'flow'. Certainly, others have linked flow more generally with successful performances: ""The high of the flow of a successful performance is something like a drug" (Sawyer, 2003, p. 42). A concept introduced by Csikszentmihalyi (1990), flow refers to an experience of heightened consciousness, when individuals are having what are termed 'peak experiences'. Such flow experiences or states can occur in many different situations, but the defining trait is that an individual, when in a flow state, is "so involved in an activity that nothing else seems to matter; the experience is so enjoyable that people will do it even at great cost, for the sheer sake of doing it" (Csikszentmihalyi, 1990, p. 4).

Some of the key characteristics of a flow state involve the feeling of control over one's actions, the disappearance of self-awareness and the feeling that time has somehow changed. Csikszentmihalyi (1990) also noted that flow states tend to appear not when individuals are passive, receptive and relaxed, but rather when their bodies or minds are "stretched to their limits in a voluntary effort to accomplish something difficult and worthwhile" (p. 3). An essential element to flow states is that the skills of an individual must be balanced with the challenges of the task, such that anxiety (too difficult a challenge with too fewer skills) and boredom (too greater skills for too easy a task) are avoided (Csikszentmihalyi, 1990).

Sawyer (2003) subsequently introduced the term 'group flow' to refer to flow states experienced when a group is performing at its peak. The critical difference between this concept and that of Csikszentmihalyi (1990) is that the state of group flow is a property of the whole group as a collective unit (Sawyer, 2003). Group flow comes into being quite naturally and always implies that the performers are in interactional synchrony (Sawyer, 2003). Groups attain and maintain flow by staying in what Sawyer (2003) has termed the 'improvisation zone' – an area between complete predictability and something so unconventional and inconsistent that it doesn't make sense. Musicians, in an improvisational setting, become highly attuned to this zone and are constantly striving to stay in it (Sawyer, 2003).

Often musical groups will talk about the need to 'warm-up' before they are able to get into a groove or flow state. Jazz trumpeter Jimmy Robinson describes "you just let [the rhythm section] play to get the kinks out. After they'd got the feeling for one another and got themselves together, then the horns joined them" (Berliner, 1994, p. 357). Group flow can be inspiring to other members of the group, encouraging musicians to play such ideas or in such a manner that would not have been possible without the inspiration of the group (Sawyer, 2003). Berliner (1994) agrees that jazz musicians often describe the importance of the group and their emergent flow or groove in lifting their own performance to a higher level.

However, there also appear to be qualitative differences between groove or good time and these rare moments of group flow, for two reasons. One, the temporality of the experience differs: in flow the experience seems to be shorter as it is referred to as a *state*, *point* or *peak* (Sawyer, 2003), whereas good time might last for extended periods if the music is truly driving. Two, the gravity of the experience differs: flow states are said to be peak experiences, the highest points of improvisation, with emphasis on the great difficulty in attaining such a state because of the delicate balance between challenge and skill (Csikszentmihalyi, 1990). Whereas for two musicians to be playing good time together, they are not necessarily pushing themselves to their respective limits – a groove can be comfortable.

5 In Summary

Music is a collective activity. Ethnomusicological scholarship has contributed a great deal to an understanding of the social foundations of making music in time with others. Music is not simply the skilled display of sounds, it involves the coordinated negotiation of individual intentions (Gratier, 2008), and as such, the expressive efforts of a collective performance are due in part to the dynamic *interaction* between its members.

This section has informed us some of the interpersonal and social dynamics of two-person interaction – of how to play well in time together with another person. Performing with *good time* in collaborative improvisation always requires an intersubjective understanding and capacity to work with the temporality of others. Individuals communicate their intentions and perceive the intentions of others – connecting interpersonally and coming to understand one another – principally through the temporal coordination of their actions (De Jaegher, 2006).

The study of temporal matching or coordination in social contexts has been extensively referred to under the heading 'interactional synchrony' (Condon & Ogston, 1966). However, there appears to be two, subtly different meanings for the term, either referring to the process by which two individuals might synchronise their actions together in time, or a quality experienced by individuals who are temporally-involved in intense engagement – the state of being mutually attuned or tuned-in to one another (Gratier, 2003; Schutz, 1951). Importantly, tuning-in involves creating a space or framework of interaction (Goffman, 1974), within which grounding of interactional content can occur (Gratier, 2008).

Furthermore, all group performance is guided in part by social and cultural conventions, which are themselves co-constructed dynamically by the group's members. The last section in this chapter has explored these conventions, with a particular focus on improvisatory settings and their rules of improvisational etiquette. The study of jazz practices is a particularly adapted means for investigating the experience of being in time together in collaborative settings, however, in order to further understand this experience at the level of pulse, we will need to take into account some of the culturally-specific rules and conventions which guide musical performance. The next chapter asks, what has musicological research brought to our understanding of how to play well in time together?

3

Music-making as Meaningful Social Collaboration

"The universal power of music excites some time-conscious source in human nature, something that reveals what is intuitively expected in human acting and the immediate experience of moving"
(Schögler & Trevarthen, 2007, p. 156).

The previous chapter has informed us of some of the interpersonal and social dynamics of two-person interaction and communication. The demands of the imaging, thinking and remembering mind, and the performing body and voice, are pushed to their limits in musical practices (Schögler & Trevarthen, 2007). Music is considered by many as one of the 'rich and mysterious sources of data' for communication research (Trevarthen, 1986). In a musical context the process of communication becomes subject to the aesthetics of playing creatively and playing with style. Music has the power to lift us 'out of time' with its intricate and majestic structures (Trevarthen, 1999), but music is not simply an ethereal abstraction existing only in the minds of isolated individuals. Music, especially improvisational real-time music, remains a discrete way of studying social communication and play, because making music also and always requires real-time, physical communication. Indeed, some believe that music can be thought of as an outward sign of human communication (Blacking, 1976).

In addition, as it will be argued here, the principles of music are grounded in physical movement itself: "even the most difficult invention and learning of music is obedient in its making to impulses felt in the body" (Schögler & Trevarthen, 2007). Music brings us down to earth and into its groove (Keil, 1994), and in response, the quality of much jazz performance is judged with reference to aesthetic principles of embodied groove and good timing – those principles which are felt and voiced by many but of which the technical nature remains unclear. This chapter asks about the contributions from musicological research to our understanding of how to play well in time together. What are some of the culturally-specific musical rules which might influence the way musicians play together and perceive their joint productions with good time?

1 Studying the Temporality of Music

There is a considerable body of both empirical and theoretical research on the temporal dimension of music, despite the lion's share of attention being paid to pitch and melody in music psychology of the 20th Century (Clarke, 1999). Dominant musicological work has taught us to conceive of music as being governed by hierarchical top-down structures in ways that parallel language (Lerdahl & Jackendoff, 1983). As a result, studies of the way in which music communicates, or the ways in which humans communicate through music, has been largely confined to describing the disembodied parts of music as imagined sound (Moran, 2007). This ethnocentric understanding of music as an abstract entity extends beyond music cognition, into many other scientific research disciplines of neuroscience, language, and into the public spheres of education and therapy (see *The Mozart Effect*).

While western approaches are typically concerned with western classical genres and intent on explaining rare levels of skill attainable in performance or the creative genius of a few great composers, other approaches acknowledge the fact that music is made and heard by every civilization known to us. Linguistics-derived musical grammars do not apply well to a great number of musical genres, including jazz, funk, hip-hop, Malian drumming, Polynesian choruses and Indian raga (to name but a few). These musics have salient features which simply have no analogue in rational language, in particular the notion of groove, which traditional musicological approaches have difficulty in explaining. "Music that grooves can sustain interest of attention for long stretches of time to an acculturated listener, even if "nothing is happening" on the musical surface" (Iyer, 2002, p. 388).

Furthermore, musicologists have traditionally studied musical scores and neglected live performance practices (Palmer, 1997; Sawyer, 2003; Stobart & Cross, 2000). The early 20th Century ideal approach was to somehow gain access to the 'composer's conception', and the most suitable means for achieving this was thought to be an analysis of the score, what Turner referred to as "textural accuracy" (1938, p. 308). This would hold true only if the score is a perfect embodiment of the composer's conception, which is not always the case, admits Turner (1938). Music is never played exactly the way it is notated in a printed score. The score is, rather, "an abstraction that does not fully represent the details of musicians' performances, just as printed text does not represent a speakers' tempo, rhythm, and intonation." (Collier & Collier, 1996).

1.1 Process and product

Every culture in the world has some form of musical tradition, and yet only a small portion of these have developed notational systems with which to represent their music; musical notation is but one of many vehicles for communicating musical thought (Schutz, 1951). One of the main reasons why musicologists have tended not to focus on performance is that it has long been considered trivial, simply a technical means for translating the score into the finger movements, breathing and bowing necessary to generate sound (Sawyer, 2003). Performance was also considered unimportant because musicologists were members of a society whose musical tradition did not value performance (Sawyer, 2003) seen only as a conduit for the genius of an absent composer (Moran, 2007). As an example, Turner in 1938 suggested that a view of the interpreter as specialist in his own right – bringing to the music something of his own – was "primitive", and "in better-informed circles this theory is rejected" (p. 308).

Rather than separating notation from performance, another division can be made between process and product, whether in composition or improvisation, distinguishing different elements of musical creation. Keil (1994) extensively dealt with the process/product distinction, and as a response to Meyer's writings on *Emotion and Meaning in Music* (1956) which focused on syntax, he argues for an analytical approach to jazz performance focusing on process. Indeed analyses focusing exclusively on structural and syntactic processes overlook crucial features of performance: the way that performances create feeling through sub-syntactical processes. However, Hodson (2007) suggests that both points of view lie at separate ends of a spectrum, with each narrowly focusing on one and ignoring the benefits of the other. In jazz, while sub-syntactical processes play an important role, musicians also use syntactical means such as "goal-oriented harmonic progressions and melodies, motivic development and recurring phrase structures to create an "architectonic" sense of deferred gratification and coherence" (p. 14). Nattiez (1990) believes that music is both process and product, such that any musical analysis must examine both the traces (the product) and processes which led to their creation.

A recent ethnographic movement however generally rejects the focus on material traces of musical composition. This ethnomusicological approach considers musical performance as essentially a form of social, pragmatic activity and uses anthropological techniques to analyse the cultural context of music-making (Blacking, 1976). Music's power at bringing and binding social beings together into a community is evidenced by the presence of some form of musical accompaniment in all ceremonies and rituals throughout history (Blacking, 1976). Such an approach places value on the experience of music-in-the-moment and embraces participative and embodied ways of understanding musical meaning.

Today there is a resurgence of analysis into performance, or as the French language expresses, the *interpretation* of musical works. For example Nicolas Donin (2007) and colleagues believe that there is a need to consider music performance as it is occurs in a situated time and place, and stresses the importance of "analysing musical works without cutting them off from those practices which allow them to exist" (p. 300)*. Cook (2001) sought to draw attention to performance and processual aspects by suggesting that musicological research should consider musical meaning through the study of its 'emergent' properties. Such studies have not only emphasized the importance of complex social, contextual and interactional processes, but have also shown that in order to fully understand performance there must be an understanding of performer-audience relationships – any analysis of group performance cannot be limited to the performers on 'show' (Blacking, 1976). The study of musical time then must also involve careful consideration of the context in which the music is performed (studio, jam-session, concert) and the audiences there to listen (either real or imagined). *("analyser les oeuvres sans les couper des pratiques qui les font exister").

1.2 Audiences and actors

The separation of music performance and music listening is a relatively modern invention, perhaps born out of a rational consideration of the disembodied mind seeking to apply universal laws of reason in an objective world (Lakoff & Johnson, 1999). This despite the fact that the vast majority of cultures make no clear distinction between their descriptions of music and dance (Merker, 1999). However in classical musical settings music listeners are generally immobile, and even a considerable number of 'popular' music concerts still provide seating. Despite musical compositions 'resonating' with the kinematics of our insides (imagine feeling a crescendo rising up through your backbone), for many the pleasure in listening remains internalized and 'secret'

(Schögler, 2002). Contemporary thought now stresses that the audience be implicated in the process of musical creation: musicians always play for an audience either real or imagined and audiences are also creators in their listening experience. Indeed music comes from community practices and is essentially communicative, so the distinction cannot remain as static performer versus passive listener.

Music performance is also intimately related to memory, defined by Schutz (1951) as "a meaningful arrangement of tones in inner time" (p. 205). Indeed, that sequence of tones may only occur in the irreversible direction of real time (from the first bar of music to the last), but the 'irreversible flux' of sound does not mean that it is so in the listener's mind (Schutz, 1951). Music listeners are in fact able to hear music in several temporal directions, referring what they hear in the present moment to what they have heard since the music began and to what they anticipate will follow (Schutz, 1951).

Some researchers have gone so far as to recognise that a listener can be thought of as the author of what he is listening to. Composer Andrea Cera and musicologist Nicolas Donin, interested in the particular ways musicians listen to different performances and in the ways musicologists 'listen' to a score they are analyzing, have named these ways of listening as 'signed' (Donin, 2004). This is because each individual listener has his own point of view and can claim his own, individual way of describing a heard musical work. Each listener has a method (more or less stable) of musical understanding unique to him – an individual trajectory of listening experience – which can then be described as being 'signed' by the listener (Donin, 2004). Musicians who perform pre-composed musical works are also known to create their own perception of the work. Fraboulet (2010) has shown for example that pianists organise their own 'extra-musical' movements – body sways, breathing and gestural head and arm trajectories – with respect to an internalized image of the work rather than to its theoretical structure.

Rather than static performer and passive audience, it may be more appropriate today to compare musical performances to a conversational exchange, and certainly in jazz contexts this metaphor is not new (Monson, 1996). How, then, do musicians talk to their audiences, and what are they trying to convey to them?

1.3 Musical terminology

In order to continue an investigation of music-making with good time, the terms tatum, tactus, beat, tempo, timing, meter and rhythm are central to this work and are defined as follows (from shorter to longer spans of time):

Tatum: The tatum (temporal atom) is the smallest subdivision of a note, which was termed by Bilmes (1993) in tribute to the jazz pianist Art Tatum.

Tactus: The tactus is the pulse level at which an individual most comfortably taps, following Lerdahl and Jackendoff's use of the term, and is said the remain between approximately 40 and 160 bpm (1983). "[The tactus] is the level of beats that is conducted and within which one most naturally coordinates foot-tapping and dance steps" (1983, p. 71).

Beat: The *beat* or *pulse* of a given musical piece refers to where musicians agree to partition time together. For example, if a beat was interpreted by a conductor it would infer the most comfortable beating speed of the baton. There are some musics which adhere to no fixed pulse – such as some contemporary classical compositions and the music called "free jazz" – but the majority of music played throughout the world has a beat, placing tone, melody and harmony across a spectrum of time. A general definition for the beat then refers to the way it partitions or divides time in music, but there are three ways of further considering the beat. Lerdahl and Jackendoff's *A Generative Theory of Tonal Music* (1983) characterises beats as duration-less time-points forming a background grid against which rhythms are measured. "Beats are idealizations, utilized by the performer and inferred by the listener from the musical signal" (p. 18). Others agree that a beat should be considered as a single, imagined point in time with no duration (Snyder, 2001). However, in electronic dance music (EDM), beats are present and powerful within the music (Butler, 2006). It is often the bass drum – the loudest and most resonant sound within the musical texture – that EDM fans and producers refer to when they describe 'the beat' (Butler, 2006). A definition of the beat then depends on whether it was fabricated by a machine or by a human: in live human performance the beat refers to how the musicians intended to structure time and how listeners infer that intention, and in electronic genres the beat is additionally an acoustic feature easily localized in the sound trace. In both cases, listeners experience the beat in the musical body, but the nature of the beat – whether it is fixed and strictly periodic or flexible and malleable – is a subject that will be discussed in detail in this thesis. It may be, for example, that:

"The beat is not to be a tyrannical cramping or driving hammer-blow, but should be to the music what the pulse-beat is to the life of a human being" (Carl Maria Friedrich Ernst von Weber, 1824).

Tempo: The tempo refers to how often time is partitioned, or how long or short the spaces are between the beats, and is also a technical description of the number of beats per time unit. Tempo can refer to either a real, physical tempo or a psychological, felt tempo. When a musician 'counts in' his group he is establishing both the beat and the tempo: musicians know that the division of time occurs with each word and is expected to continue with implied beats that are experienced or 'felt' throughout the musical piece.

Timing: The term timing can be used more or less specifically in music. It can refer to note placement and duration with respect to the beat (real or implied); it can refer to note placement and duration with respect to other musicians (from here on 'inter-musician timing'); it can refer to both; and it can be used in a more general sense still, referring to all those aspects of the music which result from the use of *time*, including general tempo and its changes.

Meter: Traditionally the meter involves a hierarchical system of accents relating to several grouping levels (Lerdahl & Jackendoff, 1983). However, a more complete and accurate description proposes that meter involves both perception and subsequent anticipation of a series of beats abstracted from the rhythmic surface of the music (London, 2004). In this respect, meter is "a perceptually emergent property of a musical sound that is an aspect of our engagement with the production and perception of tones in time" (London, 2004, p. 4), in other words, a 'periodic grouping of perceived pulses' (Iyer, 1998).

Rhythm: Rhythm in Western tonal musical genres consists of two independent elements: grouping – the ways in which music is segmented at a variety of levels – and meter – the regular alternation of strong and weak elements in the music (Clarke, 1999). However Fraisse (1984) has more generally defined rhythm as an ordered succession of elements that can be temporally distributed in either a regular (isochronous) or an irregular manner. The rhythm in this sense also refers to patterns of duration established in relation to the beat or the pulse of a musical piece (Palmer, 1997). Importantly, there is no 'ground truth' for rhythm to be found in simple measurements of an acoustic signal - the only ground truth is that upon which human listeners agree to be the rhythmic aspects of the musical content (Handel, 1989, p. 384).

2 Musical Expression and Meaning

"A piece of music will draw one in, teach one about its structures and secrets, whether one is listening or not" (Sacks, 2007, p. 211).

Music can and will always 'move' people. Even when we try very hard not to shed tears listening to the manipulative soundtrack of an overly predictable movie scene, some sort of emotional reaction can be irrepressible. "Music operates on our emotional faculty with greater intensiveness and rapidity than the product of any other art" (Hanslick, 1891, p. 107). The emotional nature of music and its strength over human affect has long intrigued researchers, artists and philosophers of life. Gabrielsson (1998) asked people to describe the 'strongest, most intense' experience of music that they had ever had, yet few were able to directly reference any specific musical element or event. Rather, individuals gave generalized accounts of 'intoxicating', 'overwhelming', 'blissful' or 'elated' experiences they had as they listened.

Yet emotional experiences are not a mysterious invention of the mind, listeners are reacting to real elements of the soundscape. Gabrielsson and Juslin (1996) performed an experiment in which musicians were instructed to perform short melodies in such a way as to render the performances with different emotional expressions to listeners. They found that expressive intentions had a significant effect on the physical characteristics performed (such as tempo, dynamics and spectrum) and in return, listeners were generally successful in decoding the intended expression. A few years later, when the musical information was reduced to timing and dynamics only in an experiment involving drumming performance, listening tests confirmed that listeners successfully perceived the emotional expressions intended (Laukka & Gabrielsson, 2000). However, there will always be a certain theatrical or exaggerated element in such a task, which may give biased or stereotypical results if one sets out to investigate natural performance characteristics.

When researchers Juslin and Laukka (2004) investigated whether people were able to consistently judge the emotional quality of musical genres from a different culture of their own, people correctly judged whether a piece of music was meant to convey a simple emotion such as joy or sadness, relatively easily. Interestingly, the most important musical element which lead to correct judgments was the tempo of the piece, such that faster music was interpreted as 'happy' or 'joyous', and slower music was interpreted as being 'sad' (Juslin & Laukka, 2004). This might be the simplest manifestation of the power of music's temporality over an experience of the musical work. Tempo, along with dynamics, are considered two universal emotional cues in instrumental music: music deemed 'sad' by most is likely to be both slow and soft. It is not always the case, but most people would tend to agree that Sibelius' *Valse Triste* or a flamenco *Soleares* both convey sadness. Conversely, music deemed 'happy' by most listeners tends to be fast-paced and at a moderately loud volume (e.g. Henry Mancini's *Baby Elephant Walk).*

Whether other elements of music such as specific harmonies or melodies convey distinct emotional qualities is debatable, such as the common tendency to equate the major/minor distinction with pleasure/pain (Meyer, 1956; Cooke, 1959). Furthermore, describing musical emotions with words is a difficult, if not entirely impossible, task: one simply cannot summarise a musical emotion with a literary description, no matter how poetic (Langer, 1942; Schutz, 1951). Despite the current and unfortunate trend of doing so – posting emotive comments at specific moments on a musical track (see *Soundcloud*) – music has for an age been considered to be more powerful than words:

> *"Ce qu'on ne peut dire et ce qu'on ne peut taire, la musique l'exprime"-*
> *"Music expresses that which cannot be said and on which it is impossible to be silent"*
> (Victor Hugo, 1864, p. 120).

2.1 Expressive and emotive music-making

Whereas teaching musical expressiveness has rarely been the focus of music education research (Broomhead, 2001), every musician strives to make their performances richly expressive and 'musical'. For many, expressive performance is the *objective* of music-making, entirely different from expression which has been pre-conceived and designed into a musical composition. Importantly, a particular musical composition can elicit emotion in theory, but in practice, a precise performance of the music can also be emotionally empty, indeed, mechanically-exact performance rarely makes a "satisfactory performance" (Sloboda, 1988, p. 10). The discrepancies between human performance and music notation constitute an essential part of musical communication (Sundberg, 1988). By varying timing, dynamics, pitch and timbre, musicians can emphasise specific events in a musical performance, downplay others, and shape performances into meaningful, expressive lines and textures. A musical work can never be played in exactly the same way by two different persons nor by the same person in two different contexts (Palmer, 1997; Schutz, 1951). Additionally, musical performance always conveys a musician's interpretation of the musical composition (Fraboulet, 2010), involving "performers' individualistic modeling of a piece according to their own ideas or musical intentions" (Palmer, 1997, p. 119).

In the early 20th century, musicological scholarship emphasised that the subtle manipulation of harmony and melody alone were responsible for musical expression, a focus on *where* notes were placed. However, while rhythms can exist without melody, melodies cannot exist without having been structured and expressed in time. There are three variables with which musicians are able to control *when* and *how* notes and rhythms are placed in time: note placement and duration (timing), note intensity (dynamics), and to a lesser extent note articulation (manipulating the instrument's timbre)(Clynes, 1986; Laukka & Gabrielsson, 2000; Seashore, 1938). Rhythm and *expressive timing* have classically been viewed as lesser musical qualities, but in most of the musical traditions born in Africa for example, rhythms played together with others are the basis for musical expression. Such a rhythmic basis is often viewed as being indicative of its 'simplicity' or lack of sophistication, however, according to contemporary musicological thought, it is precisely the complexity that comes from the subtle manipulation of rhythm that affords expression in music (Schögler, 2002). Furthermore, the ethnocentrism of emphasizing the importance of harmonic structure over rhythmic features is simply not compatible with music being understood as embodied activity (Moran, 2007).

A second line of questioning from musicological research on the expressivity of music concerned the formal structures of music. 'Formalist' scholarship argued that understanding expression was the result of an intellectual process dependent on an understanding of the deep structural relationships of a musical work. For example, Lerdahl and Jackendoff (1983) sought to describe rhythm in terms of its organizational and structural principles, based on Chomskian linguistics theory and Gestalt theories of form and grouping. Music performance has often been discussed in relation to the ways in which it reflects structural organisation, and performance expression is said to provide listeners with acoustic cues that facilitate the analysis of that structure

(Clarke, 1987, 1999; Drake & Palmer, 1993; Gabrielsson, 1988; Istok et al., 2008; Palmer, 1997; Repp, 1992; Sloboda, 1985).

Others have emphasised the importance of motional aspects of performance expression: physical movements during music-making are also fundamental for the display and interpretation of an expressive performance (Gabrielsson, 1999). Several recent studies have shown that musicians' movements visually convey both structural and expressive information (Broughton & Stevens, 2009; Dahl, 2006; Juslin & Laukka, 2003; Nusseck & Wanderley, 2009; Wanderley, 2002). Researchers distinguish between two types of movement in musical performance: instrumental actions that are necessary for sound production and those 'ancillary' or expressive movements which, although being non-essential for that performance, represent a link between the music and the expressive intention of the musician. Ancillary movements occur frequently in musical performances (Wanderley, 2002), and researchers are now investigating those precise aspects of ancillary motion kinematics which may convey expressive information and influence perception (Nusseck & Wanderley, 2009).

Perceiving musical expression

Given that musicians systematically perform with timing variations, listeners should be able to hear such variations. This is generally the case: measurable stylistic performer differences are also measurable in the perceptual realm – they are heard and can be rated by expert musicians and novices alike. For example, listeners are able to decide whether an audio recording is real or tempo-transformed (originally performed at another tempo, but made similar in overall tempo), on the basis of expressive timing judgments (Honing, 2006). In addition, non-musician listeners are able to successfully distinguish between mechanical (inexpressive), expressive, and exaggerated levels of performance as accurately as musician listeners (Kendall & Carterette, 1990).

A second presumption is that listeners will also expect to hear and prefer music performance with naturalistic timing deviations. Indeed, when forming aesthetic judgments, anecdotally music without expressive timing generally sounds 'dull', and music with unusual or random timing sounds 'bad' or 'wrong' (Repp, 1998b). Most music listeners would agree with this notion, at least if they are familiar with the musical style. In an investigation measuring somewhat indirectly the extent to which people prefer naturalistic timing, Clarke (1993) used computer-recorded performances and systematically perturbed some of the natural rhythm patterns present. When pianists were asked to imitate or replicate performances they heard, they had more difficulty with the ones that were rhythmically perturbed than ones with natural rhythms present (Clarke, 1993).

Conveying expression in musical performance

But how do musicians manipulate sounds, structures and movements in time together to induce such universally-consistent emotions in listeners? Revolutionary work in the 1950s came from Leonard Meyer (1956), who departed from the 'formalist' viewpoint and chose an 'expressionist' stance by proposing that there was something inherent in the music that evokes an emotional reaction in the listener and meaning is constructed from this. Meyer (1956) then put forward a theory of how aesthetic affect in music has intimate ties with expectation – that musical emotions come not from having our expectations met but from having them thwarted. For Meyer, uncertainty about an outcome is what creates pleasure, and predictability is wholly dissatisfying. Certainly, as Turner and Pöppel (1983) commented, the human nervous system is *habituative* – essentially built to register differences. Our nervous system is designed to ignore repeated and expected stimuli and respond only to the new and unexpected; it is "more interested in odd answers than ordinary ones" (Turner & Pöppel, 1983, p. 279).

Elaborating on this idea, Huron (2006) suggested that the ability to develop these expectations is innate, as anticipating and expecting where and when things will happen might have been an evolutionary advantage. In this respect, good predictions should be rewarded and mistaken ones be punished in order to encourage those successful predictions. However, if our predictions were always correct, aided by an effective memory of past actions, according to Meyer's theory, no pleasant affect should come from such an anticipated scenario. Rather, experience gained through music listening allows us to develop 'schemas' against which to evaluate the music (Meyer, 1956). 'Intelligent mental play' and 'affective experience' are complementary, and are importantly dependent on musical deviations from the schemas created of that music (Meyer, 1956).

There are several means by which composers (and improvising performers) manipulate musical material in order to toy with our expectations. These include (although the list is not exhaustive): syncopating rhythms – shifting emphasis from the onbeat to the offbeat; using tonal ambiguity and chromaticism; manipulating harmonic expectation (suspensions), cadences and endings; and playing with expectations of style and genre. These compositional techniques are said to incite cycles of affective tension and release, and for pre-twentieth century composers, harmony and tonality rather than rhythm provided the most important means for doing so (Ball, 2010b).

2.2 Expression through performance deviation

One further insight into musical expression comes from the notion of performance deviation itself. Rather than emotions being reflected by simplistic, general qualities of the music such as slow tempo or quiet dynamics, much of the feeling in music is evoked *because of* the small changes or deviations from perfect or prescribed mechanistic performances. Musicians, audiences and theorists alike often mention how life and expression in music comes from that which is 'on top of' or 'in addition to' composed notes and score markings (Ball, 2010b; Collier & Collier, 1996; Meyer, 1956; Seashore, 1938; Todd, 1985).

The importance of adding performance deviations is certainly not a recent musical development, as Thomas Mace suggests in 1676:

> *"although in our First Undertakings, we ought to strive, for the most Exact Habit, of Time-keeping […] yet, when we come to be Masters, so that we can command all manner of Time, at our own Pleasures, we Then take Liberty […] to break Time; sometimes Faster and sometimes Slower, as we perceive, the Nature of the Thing Requires, which often adds, much Grace, and Luster, to the Performance"* (Mace, 1676, p. 81).

When Carl Seashore began investigating music performance empirically early in the 20th Century, he too came to the conclusion that the key to expression in music is deviation:

> *"The unlimited resources for vocal and instrumental expression lie in artistic deviation from the pure, the true, the exact, the perfect, the rigid, the even, and the precise. This deviation from the exact is, on the whole, the medium for the creation of the beautiful – for the conveying of emotion."* (Seashore, 1938, p. 155).

Performers are able to generate substantial temporal deviations from the nominal values given by the score. These deviations are used for expression, but specifically, they are expressive precisely because they deviate from a norm or cultural convention (Meyer, 1956). For this reason, deviations cannot be infinitely large; additionally, depending on a number of other musical features of a performance (such as the tempo or the complexity of rhythms), musicians must be expressive within certain boundaries in order not to interrupt the perceived pulse (Madison & Merker, 2002). Yet pushing those boundaries can be a way of teasing the listener's appreciation for the music as it unfolds, as rhythmic ambiguity is often an important aspect of tension creation (Stobart & Cross, 2000).

Deviations are not simply random mistakes caused by poor technique, but intentional acts performed for expressive purposes. Humans can produce highly precise temporal movements as well as expressive timing variation (see Chapter 1). This implies either that musicians must learn and perfect timing variations to be able to incorporate them into their performances, or that variations are *a reflection of the intuitive ways musicians coordinate their movements in time*, in order "to satisfy immediately apparent motives" (Schögler, 2002, p. 42).

There is evidence for both. Some variations are intentional and controlled: for a given musical piece, musicians can replicate their expressive performances with high precision (Gabrielsson, 1988; Seashore, 1938; Shaffer & Todd, 1987) and when musicians are instructed to perform with exaggerated expression, patterns of expressive timing and dynamics are increased (Palmer, 1997). In addition, the stylistic conventions of particular musical genres can also determine the extent to which deviations are used. Most musicians are aware that there are implicit rules of stylistic deviance specific to each musical idiom, which govern how a performance should differ from a purely mechanical representation of the notated score (for example in a *March* very little tempo fluctuation is permitted, yet large variability is expected in a *Beethoven sonata*)(Gabrielsson, 1988). Furthermore, each performance is a reflection of an individual's interpretation of the musical work, hence some deviations highlight a personal interpretation of culturally-defined musical material (Fraboulet, 2010; Gabrielsson, 1999; Schutz, 1951).

Iyer (1998) suggests that expressive timing is in fact what differentiates 'groove-based' musical genres from western classical ones, but all music, when performed, exhibits natural variation from machine-like re-production. This suggests that other variations are less intentional, instinctive, and a reflection of the way musicians shape musical motives over time. Repp (1998c) agrees with an instinctive level of variation: "the magnitude of expressive timing variations in realistic performance is under musicians' control, but underlying them there may be smaller, involuntary tendencies" (p. 792). In every performance there are deviations from mechanical production, from how a machine would perform a notated piece (Palmer, 1997; Rasch, 1988). When pianists are asked to play "metronomically" (with perfectly even timing), they continue to produce systematic timing variations which resemble the larger timing variations found in expressive performance (Penel & Drake, 1998; Repp, 1999a; Drake & Palmer, 1993; Palmer, 1989; Seashore, 1938). In other words, attempts to perform mechanically significantly dampen the patterns of expression but do not remove them altogether – residual, unintentional timing variations remain (Bengtsson & Gabrielsson, 1977; Loehr & Palmer, 2009a; Palmer, 1989; Seashore, 1938).

2.3 Expression through dynamic 'feeling forms' of tension and release

Aside from the presence of temporal and melodic deviation, another clue to music with *good time* comes from the organisation of expression over time. In the 19th century, Herbert Spencer (1862) noticed that acoustic indicators of simple emotions such as happiness, sadness, anger and fear were common to human speech patterns, even amidst people of many different cultures. He then suggested that this is because such emotions have physiological effects on the vocal apparatus. For example, angry speech seems to be fast and loud, sad speech is slow and quiet and happy speech is fast with medium volume. This notion – that emotive musical sounds imitate the physicality of that emotion in people's speech – might easily be extended to include gesture, as people who are unhappy tend to speak and move both slowly and softly. Clynes (1977) too postulated that emotions were associated with a specific pattern of brain activity and could be expressed in different modalities – such as gestures, facial expressions and musical phrase – with the same dynamic form.

While formalists were studying the structural properties of music, one somewhat underground proposition came from Suzanne Langer (1942), who introduced the notion that music induces emotional states that have a quality of their own. Rather than a lexically-biased description of musical emotion evoking categorical and concise emotions, music evokes ambiguous expression or non-specific symbolism. "Music is revealing where words are obscuring" (Langer, 1942, p. 243). Rather than representing emotions, music in fact *mimics* them, as the ebb and flow of music is analogous to the dynamics of the emotions themselves (Langer, 1942). Langer (1942) terms these dynamics 'forms of human feeling', and cites them as congruent with formal properties of music such as patterns of motion and rest, of tension and release, of agreement and disagreement, preparation, excitation and fulfillment.

Langer's (1953) view that the structure of music is isomorphic to the structure of feeling echoes loudly the works of Stern (2000), Trevarthen (1999) and Imberty (2005) cited in Chapter 1.

Cycles of tension and release with respect to melodic and harmonic expectation were mapped by Meyer's student Eugene Narmour (1991). Narmour's (1991) model suggests that music's emotional effects are the result of formal and structural relationships between notes, such as differences in the status of notes in the diatonic scales and the gestalt implications of melodies. "The expectations that arise from these mental schemas set up a constant flux of tension and release as a melody threads its way through pitch space. The composer artfully weaves that succession into a pattern of satisfying and stimulating contour" (Ball, 2010b, p. 310). Such emotional effects were also studied by Lerdahl (1996), by giving listeners a 'tension slider' to manipulate upwards or downwards in real time as they listened to musical samples. The obtained 'tension profiles' were found to be highly consistent between different listeners, implicating that the idea of tension and release objectively exists in people's minds (Lerdahl, 1996).

It is the subtle manipulation of rhythm that principally affords the emotive qualities and feelings which arise in music-making and music-listening (Schögler, 2002). In addition, there are strong indications that expression in music is conveyed through the subtle interplay between uncertainty and expectation, the manipulation of tension and release, and an ebb and flow analogous to dynamic and deviant forms of the emotions themselves. Just how musicians negotiate this subtle interplay together in time demands further exploration.

3 Shaping Time in Musical Performance

There is an extensive database of psychological research on expressive timing in the performance of classical genres, dating back to the seminal work of Carl Seashore in the 1930s, and even earlier (Collier & Collier, 1996). Reflective of the division between pulse-level and narrative-level communication in the theory of Communicative Musicality (Malloch & Trevarthen, 2009), and stemming from Osborne's (2009) multiple timescales of temporal thought and action, I have chosen to organise the following aspects of expressive timing research by grouping them under two headings: those which relate to a *pulse* level and those which relate to a *form* level. Brown (1979) too proposes a distinction between two related notions of timing: a) "the relationships and tensions between regular underlying beat, meter and note values", and b) "the feeling of progression towards a hierarchy of musical goals, from the beat, accent and phrase-end through to longer-term and more 'unconscious' temporal goals" (p. 19).

♫ By pulse-level timing I am referring to smaller-scale note timing and rhythm – all those aspects of the musical soundscape which are performed and experienced *in the moment*. The pulse level here includes Todd's (1985) *local component* which involves fluctuations at the note level and micro-timing. Todd's (1985) work however ignores local components as they "seem to be determined largely by stress patterns and metrical structure at the surface" (p. 40), echoing a limited, formalist view of their purpose.

♫ By form-level timing I am referring to longer spans of musical time, including gradual changes in tempo, macro-rhythmic structures and narrative phrase – all those aspects of the expanded musical soundscape which are performed and experienced dynamically *over time*. The form level is a combination of Todd's (1985) global component which incorporates tempo variation over the whole piece and his intermediate component involving smaller tempi changes or *rubati*. However, it is believed that the separation of these two is unjustifiable, as it is unknown when a shorter instance of *rubati* becomes a significantly longer tempo change.

They are inter-dependent qualities, as the coordination of pulse is what generates the larger, co-constructed rhythmic forms (Schögler, 2002). "Large-scale musical form *emerges* from an improvisatory treatment of these short-range musical ingredients […] from the ways in which musical variation is executed 'in time' (Iyer, 2004, p. 163). In addition, some aspects of musical form can stem from "a collective experience of shared, lived time" (Iyer, 2004). I have chosen not to divide this work into its constituent syntactical and semantic elements, as both large-scale and small-scale timing can be reflective of syntactical process, and both can have meaning (Kühl, 2008). Importantly then, as individuals can be aware of both smaller- and larger-scale elements of the soundscape at once, the meanings and feelings involved in the experience of *good time* may plausibly be a function of both pulse-level and form-level expressive timing.

3.1 Musical expression at the pulse level

Pulse-level deviations are used to convey expression (Repp, 1998c), and to contribute to defining style and expressive musicality (Bengtsson & Gabrielsson, 1977). Importantly, expressive timing can be remarkably stable over repeated performances, even those spanning a number of years (Clynes & Walker, 1986). When Repp (1998c) studied the timing profiles of nine pianists who played Chopin's Etude in E major, he found that some inter-onset intervals (IOIs) were 100-150ms longer than others, calculated as over 30% of the typical IOI. In addition, when 115 commercially-available performances of the same piece were studied, deviations ranged from 10% to 30% (Repp, 1998c). Pulse-level deviations are clearly both ubiquitous and sizeable (as large as 150ms) in musical performance.

Researchers have now demonstrated that performance is characterised by *systematic* variations in note durations in relation to the mechanical regularity of the notated score (Bengtsson & Gabrielsson, 1977; Gabrielsson, 1988), and in relation to certain emotions conveyed. For example, researchers investigated 'happy', 'sad', 'angry', 'fearful', 'tender', 'solemn' and 'not expressive' performances, and found that timing patterns were particularly important for the expression of fear and happiness, in both piano performance (Juslin & Madison, 1999) and drumming performance (Laukka & Gabrielsson, 2000). Interestingly, fear was associated with by far the largest local timing deviations (Juslin & Madison, 1999; Laukka & Gabrielsson, 2000). There are several timing patterns at the pulse level which have been described in musical performance, including: structural deviations (Todd, 1985); physical constraint-related deviations; chord asynchronies and melody lead (Palmer, 1989); and inter-musician asynchronies.

Micro-temporal characteristics of classical music performance are widely seen as the generative consequence of how a performer conceives the structure of a musical work (Clarke, 1987, 1999; Desain & Honing, 1994; Drake & Palmer, 1993; Honing, 2001; Madison & Merker, 2002; Palmer, 1989; Repp, 1992; Todd, 1985). For example, one of the central theses of Todd's (1985) model of expressive timing in tonal music suggests that a performer uses final phrase-lengthening (slowing down at a boundary) as a device to reflect the underlying structure of a musical work and that the degree of slowing at an ending will reflect the hierarchical structure itself. Another early example comes from Povel (1977), who examined note durations for a brief segment of a Bach piece and discovered that notes of equal length in the written score were played longer or shorter, depending on their position in the bar. Shaffer and Todd (1987) extended this approach from notes to measures and found that the duration of a measure varied subtly, depending on its position within a phrase. With respect to metrical context too, Clarke (1999) assessed piano performance deviations and found that notes in strong metrical positions tended to be lengthened and notes in weak metrical positions tended to be shortened.

Another explanation for micro-temporal deviations is that they reflect specific constraints imposed by the instrument or by physical embodiment. For example a trill between two adjacent notes on the piano will be played differently to an octave tremolo because of the physical stretching of the hand – a summary of physical constraints and abilities has been provided in Chapter 1. Expressive timing for example has been shown to vary considerably with regard to the global tempo: at very high tempi, adapting the size of deviations used to perform fast trills or vibrato with equal expression becomes challenging due to the physical limitations of the fingers, limbs and lungs (Desain & Honing, 1994).

One ubiquitous timing pattern seen at the pulse level is that of chord asynchronies, which refer to the asynchrony between musical events notated as synchronous (Palmer, 1989). For three-note chords, differences in onset times between pairs of voices were calculated by Palmer (1989), who found that asynchronies averaged around 20ms. However, when musicians were instructed to create 'unmusical' or 'deadpan' performances, onset asynchronies between notes were smaller – around 10ms on average (Palmer, 1989). In other words, in the more expressive performances, the chords were arpeggiated or staggered to a greater extent, a clear indication that performers have control over the quantity of synchronisation between voices. In addition, Palmer (1989) showed that 'expert' musicians tended to arpeggiate the chords more than novices, indicating that the ability to perform with asynchrony is considered a skill.

A further proposition is that deviations may facilitate the perception of multiple voices or notes which, in theory, occur at the same time, known as auditory stream segregation (Iyer, 2002). One early investigation of this was performed by Vernon (1937), who found that pianists played notes belonging to the melodic voice sooner than others notated simultaneously; this phenomenon came to be known as 'melody lead', which is said to separate voices perceptually (Palmer, 1997). In Palmer's (1989) study of performed chord asynchronies, she found that melody notes tended to precede other voices by roughly 20ms in the musical performances, both on average, and on an individual basis for each performer. When beat position was taken into consideration, the melodic line preceded the other voices most often on the beginning of each measure, an effect which was exaggerated in 'musical' versus 'deadpan' performances (Palmer, 1989).

Interpersonal ensemble timing

How do musicians entrain to the subjective pulse and subjective meter inferred from other musicians' performances? An alternative explanation for performance deviation is that it is a result of the process of coordination or synchronisation between musicians. Several studies have researched the subtleties of expressive timing (see Clarke, 1999), fewer studies have concentrated on communicative, *interpersonal* subtleties of timing in an ensemble. Ensemble members must accurately synchronise their individual performances together in order to produce a satisfactory performance (Rasch, 1979), but their coordination is also a collaborative endeavour that holds aesthetic value in itself (see Chapter 2). Performers clearly need to play in time with others in order to convey coherent musical ideas, but surely the process by which musicians coordinate their actions and ideas together in time reveals communicative gaps of asynchrony *in addition to which* expressive deviations can be added to convey other qualities in the musical mix.

Musical contexts greatly facilitate the task of coordination relative to synchronisation with inanimate objects. As an indication of this, the negative mean asynchrony that exists in tapping tasks is heavily reduced in natural rhythmic and melodic contexts (Loehr, Large & Palmer, 2011). For smaller ensembles, coordination involves watching and listening to each other for temporal and rhythmic cues (Luck & Nte, 2008), and for larger ensembles, a conductor typically provides the rhythmic beat which the musicians must watch and listen for. Significant work in this area has been conducted by Clayton (1986), who investigated the timing accuracy of string players and their reliance on different timing information available to guide their actions. Participants were required to perform a piece of music alongside a combination of different sources of timing information, including (1) the other ensemble players, (2) the conductor, (3) the score, and (4) the player's own sense of rhythm (Clayton, 1986). The two most important influences were found to be firstly the other ensemble players and secondly the conductor (Clayton, 1986). The conductor's role was apparently to provide general timing information to the ensemble "such as setting up the initial tempo and monitor this tempo across time, keeping the musicians generally 'together'" (Luck & Nte, 2008, p. 84). However, a player's ability to perform their movements with temporal precision was clearly *most* reliant on the players listening to their fellow ensemble musicians (Clayton, 1986). Listening attentively to each other is a necessary and valued skill in musical performance, not only to demonstrate social involvement, but in order to coordinate temporally with others.

There is no doubt that the process of coordination in an ensemble reveals timing discrepancies between the performed notes of musicians: "perfect synchronisation is not possible in live performance" (Rasch, 1988, p. 71), despite scattered findings on the ranges and averages of discrepancies cited. Rasch (1988) measured asynchronisation amongst the voices of different instruments supposed to produce tones at the same time in classical recorder, wind and string trios, and found that differences in onset times varied between 30 and 50ms. In addition, in the string ensembles he found that instrumental roles also had an effect on note placement: on average, the violin tended to lead by 5-10ms, the cello followed, and the viola tended to lag by another 5-10ms. Goebl and Palmer (2009) recently investigated timing between two pianists performing duets together and found an average timing discrepancy of around 10ms (in the full auditory feedback condition), and a range of approximately +/- 50ms (taken from Figure 2a, p. 431).

As an extension to this work, researchers have been investigating different influential factors on the ability to and precision with which musicians synchronise their actions together. Goebl and Palmer (2009) found that the note ratio (number of notes played in comparison to the other player) had an influence on the asynchronisation produced: the pianist playing more notes tended to play before the other. Hierarchical roles were also investigated, but the tendency was not for the ascribed 'leader' to play either ahead of or behind the other (Goebl & Palmer, 2009). In another study, it was found generally that performances at faster tempos were more tightly synchronised (Loehr & Palmer, 2009b), a finding in keeping with the result that tapping variability decreases as the tempo accelerates (Semjen, Schulze, & Vorberg, 2000).

Ensemble timing is also logically a function of the size of the musical ensemble itself. Tight or precise timing might be a necessity when sizeable orchestras come together to rehearse a piece, at least to begin with. Larger groups will have an increased range of performance deviations as each individual's natural fluctuations will combine with others, but it must also be in part because each musician has their own interpretation of a musical work (Donin, 2004; Fraboulet, 2010; Gabrielsson, 1999). Learning to play in time together then also involves the synchronisation of individual motives (Malloch & Trevarthen, 2009). When musicians are performing different musical parts, each with their own expressive markings on individual scores, each will have a slightly different notion of how melodic gestures should be conveyed in terms of their expressive and dynamic shape. To facilitate this expression in orchestral and chamber settings, there is often a conductor or lead musician who is responsible for guiding the expressivity of others. Indeed the conductor's role has changed over time: previously a simple time-beater they are now also considered as interpreters and communicators of the emotional content of the music, providing both temporal and expressive information to the ensemble (Luck & Nte, 2008).

There are always temporal deviations from exact synchronisation between musicians, yet the size and distribution of asynchronies cited must also be dependent on subtly different ways of asking musicians to perform. If, in some studies, musicians are requested to play 'precisely' together, and in others, musicians are asked to perform 'expressively' or 'musically', then remaining traces of asynchrony may be significantly different. Musicians are perfectly capable of performing with almost no asynchrony (see Chapter 1, section 1.3.2), but there has been little investigation into the extent of expressive and communicative deviations present in naturalistic performance settings.

The perception of pulse-level deviation

There have been few experimental studies to investigate the perception of micro-timing variation in musical performance. Bilmes (1993) performed an experiment in which resynthesised drum recordings were played to subjects, who then made an aesthetic judgment on them. The technique used to extract deviation timing from the recordings was to extract note onset times (with each drum on a different track), calculate the tempo, what he terms the 'tatum grid times' (i.e. where mechanical onsets would occur) and actual microtiming deviations (Bilmes, 1993). He then recreated the performances, with the extracted timing and tempo deviations added back to the quantised attack times, or with random Gaussian deviations added (using the same mean and standard deviations as the original performances). Most listeners found the quantised, undeviated version "mechanical"; the random variation version "sloppy" or "random"; and said the version with the correct deviations added sounded most like the original. Interestingly, within versions with the correct deviations added, Bilmes (1993) additionally found that tempo variation was not as important as timing deviation. In general, without timing deviations the performance sounded 'colourless and cold' and with them it sounded 'rich and alive' (Bilmes, 1993). Consequently, Bilmes (1993) proposed that combining both tempo variation and timing deviations could eventually produce the full effect of rhythmic expressivity.

With respect to whether individuals notice when asynchrony occurs at particular moments in musical performance relative to others, Repp (1992) again has performed significant work. When small local deviations from temporal regularity are introduced in a computer-controlled, evenly timed performance of piano music, their detectability depends strongly on their position within the musical work (Repp, 1992). For example at phrase boundaries, listeners' abilities to detect a timing perturbation declines markedly, but in the middle of phrases, listeners' detection scores reached their peak values (Repp, 1992). This finding may be a reflection of listeners' cognitive expectations of expressive timing, as listeners expect to hear greater timing deviations at boundaries through their experience of hearing them repeatedly in performance, an interpretation favored by Repp (1992).

The perception of asynchrony – of temporal gaps *between* the performed notes of musicians – has received little scientific interest. With regards to the specific size of asynchrony perceived in musical contexts, we might expect the just noticeable difference (JND) to be considerably larger than Hirsh's (1959) established 20ms, due to the complexity of information available. Indeed in Rose's (1989) study of microtiming in rhythm section performance, he concludes that "onset time differences of 20ms or less are unlikely to be perceived when they occur in musical or 'pseudo-musical' settings" (p. 113). By setting the onset times so that the perceived attack of musical notes appears simultaneous – the perception of perfect synchrony – Gordon (1987) found that onset times could be within 20ms to maintain the perception of simultaneity. Yet earlier, in perhaps one of the original studies of temporal perception, it was shown that experienced musicians are able to perceive temporal asynchronisations as small as 10ms between the onsets of two notes on a piano (Vernon, 1937). Others imply that human sensitivity to asynchrony is heightened in musically-rich contexts. Michon (2000) for example comments that "linguistically and musically meaningful sounds show vastly lower temporal order thresholds than meaningless sounds such as beeps" (p. 88).

There is an indication that individuals can perceive very small timing deviations, and to a certain extent may expect to hear those deviations in natural, musical play, in particular at specific moments in a musical work. However, just as interpersonal aspects of deviation in musical performance have been under-examined, the perception of interpersonal timing also requires further study, especially in musically-rich and naturalistic contexts.

3.2 Musical expression at the form level

As musical pulse and form are inter-dependent qualities, there also needs to be a focus on larger-scale co-constructed forms which emerge from the dynamic process of music-making. Performance timing can also exhibit stability at larger levels, including entire musical pieces. Clynes and Walker (1986) found that over repeated performances by the same musicians, the total durations of musical works performed by string quartets were highly consistent: standard deviations were around 1%. In fact the standard deviations were smaller than that of individual movements within the piece, such that if one movement was shortened, another was compensated for in duration (Clynes & Walker 1986). This demonstrates that "the overall time concept of a piece can exist in the context of social music making [..] as a collective mental concept" (Clynes, 1986, p. 197).

In contrast, it has been shown that individuals exhibit the tendency to gradually and systematically speed up as they perform (Drake, 1968), but when this happens, they are said to *rush*, and similarly when musicians unintentionally slow down the music is said to *drag*. Musicians generally consider unintentional changes in speed undesirable, which is why such terms carry a negative connotation. In Clynes' (1986) analysis of the performances of Janacek's string quartet No. 2, he observes how stability develops over time. In the first four performances, each of the four movements were performed firstly relatively slow, then slightly faster, faster still, then slightly slower, and from the fifth performance onwards each section length remained relatively stable. Clynes (1986) noticed and highlighted this distinction between what he terms 'developing' performances or 'training phases' and 'stable' ones (Figure 11, p. 197). This indicates that in the first four performances, the musicians were trying to establish the ideal pace for this piece of music, according to their own preferences. In successful performances then, musicians have clearly worked together to control longer spans of time, through their moment-to-moment control of speed.

Tempo

In musical terminology, the tempo is the speed or pace of a given musical work, and is a crucial element of any musical composition as it can affect the mood (Gabrielsson, 1995) and the difficulty of a piece. The tempo is typically written at the beginning of a musical work and in modern Western music it is customary to indicate a note value (crotchet, quaver) and the number of those notes or beats to be played per minute (BPM, e.g. ♪ = 120). Whether a musical work has a mathematical time indication or not, in classical Western music the tempo is usually described by one or more markings in Italian, and these descriptors clearly make reference to physical movements (e.g. *adagio* = funeral pace; *andante* = walking; *allegro* = quick march; *presto* = running)(Pieron, 1945). Each tempo description usually has an associated range of acceptable tempi, however, musical period, style and national temperament may also affect the range for any given marking (Brown, 1979). Brown (1979) suggests that the tempo of a musical performance must incorporate two distinct notions. Performing movements in any situation are limited to a series of discrete, physically-possible tempi whose origins lie in a fundamental biological periodicity (Chapter 1, section 1.3). At the same time, performing tempi are determined by the nature of the musical material itself. The selected tempo in fact depends on various elements, including: "musical, performing, instrumental, environmental, and psychological factors [..] individual temperament, mood, previous activity, knowledge, perception, experience, taste and current interpretative view" (Brown, 1979, p. 31).

Alongside tempo indications in classical Western music, separate markings in Italian are often used to indicate the general mood of the piece, such as *agitato* (agitated) and a*ppassionato* (passionate), providing a clear link between tempo and affective quality in music. "Of the variables which give meaning to music, tempo plays the largest role" (Farnsworth, 1969, p. 83). Tempo variation is a valuable means of expression (Brown 1979; Gabrielsson, 1995; Turner, 1938) and there are several indications of this, both from researchers' findings and musicians' personal experiences. When describing the affective quality of a piece of music, Farnsworth (1969) found that individuals were most likely to change their description whenever the tempo is significantly slowed down or sped up, and other musical features were far less likely to influence the listeners' choice of words used to describe the piece of music they are listening to. One of the main reasons Turner in 1938 believed that the score was 'faulty' and could not be a perfect embodiment of a composer's conception was because of the methods used to indicate tempo. From a developmental perspective, Thackray (1969) noticed that tempo stability is the component which improves the least as a function of age, as the ability to maintain a regular temporal pulse is evident from early on and changes little. Moran's (2007) musicians also emphasised the importance of tempo in North Indian music performance:

> *"In India, we call the tempo […] when there are two humans interacting together, a sitar player and a tabla player, the tempo between them is described in Hindi language as zindalay. It's the tempo which is life. It's the tempo which is vibrant."* (Arvind Parikh, Interview 3, in Moran, 2007).

In electronic dance music (EDM), tempo is a recurring technique used to create intensity: "...tempo is a driving force. The tempo of music can take people up and it can take them down." (Jimmi Journey, in Butler, 2006, p. 251). Several performers indicated that they intentionally increase the tempo in performance but only by slight amounts, as the audience's physical response is also crucial – there a limited range of physically comfortable tempi in which to dance. "Just a few beats per minute really makes a difference" (Mystik, in Butler, 2006, p. 252). At the same time, DJs do not change tempo too radically because particular tempo ranges are associated with musical genres within

EDM (e.g. house, techno, jungle). Tempo is a widely-used means for creating intensity, but musicians are not always intentionally using tempo to this effect: "it kind of speeds up on its own […] but I don't do it consciously" (DJ Shiva, in Butler, 2006, p. 253).

Expressive performances of Western musical genres are often characterised by continuous tempo modulations (Repp, 1998 Variations), including *accelerandi* (speeding up) and *ritardandi* (slowing down). This style of playing, called *rubato*, became especially favoured during the Romantic era (Ball, 2010b). There have been several investigations of this in classical performance. Palmer (1989) found that expressive, musical performances were characterized by significantly greater use of *rubato* than in unmusical performances for 5 of the 6 pianists studied. Additionally in Laukka and Gabrielsson's (2000) study of expressive drumming, not only did they associate specific emotions with significant local timing deviations, they also associated expressivity with significant global changes in tempo. The *rubato* style has often been contrasted with African or 'groove-based' musical genres which are said to observe temporal and metrical regularity with far greater precision (Ball, 2010b; Iyer, 1998). However, in groove-based musical genres, even the simplest of repetitive rhythmic patterns can be imbued with a 'universe of expression' (Iyer, 2002, p. 396).

The shaping of musical time

To return to classical Western genres, changes in tempo do not occur randomly, they are intimately related to the expression of the musical content and form. Clarke (1999) notes that there is often a pattern of *accelerando* and *ritardando* in each phrase, as well as considerable tempo variations in larger sections. R*allentandi* most often occur either at the end of the musical work or at boundaries between sections within the work, and generally, the slowing increases smoothly and is greatest for the final note. One of the most salient timing patterns found both in music and speech, is the tendency to gradually and considerably slow down (*rallentando*) at the end of an action or sequence (Todd, 1985), and the placement of pauses at phrase boundaries (Palmer, 1989), collectively known as *final phrase lengthening.* The *final retard* is the last instance of final phrase lengthening to be used at the very end of a musical work.

This changing tempi shape – an initial accelerando and final ritardando – can be described as a 'phrase arch', and has been observed in many previous analyses of musical works (Friberg, 1995; Gabrielsson, 1988; Repp, 1992; Shaffer & Todd, 1987). Researchers found that the shape is sensitive to both musical style – in romantic music the arch is used more extensively than in Baroque music for instance – and 'personal taste', as there is large variation seen in performances of the same piece played by different performers. Music theorists have traditionally classified a phrase in harmonic or tonal terms, as something which projects tonal motion, progressing from one harmony to another and either returning to the same harmony or ending with a different one. Phrases in this way usually close with a cadence as the final part of the last harmonic progression, carrying with it harmonic finality. However, in more general terms phrases are rhythmic events that unfold in time (Butler, 2006), and *phrasing* can be a way of shaping time through tension and relaxation (Imberty, 1979, 1981), of giving impulse and direction to the flow of patterned sound (Gratier, 2008). The dynamic form of such a phrase resembles that of human movement, with a rise to a central point of effort and a decline at the end (Stetson, 1905).

For example electronic dance music (EDM) professionals are not particularly concerned with establishing a sense of tonal motion or harmonic progression, and EDM music contains few or no cadences (Butler, 2006). Phrasing in EDM exists in other forms, and for both Disc Jockeys (DJs) and producers of EDM music this phrasing is a crucial structural feature of the music, created actively by DJs in their manipulation of different musical tracks. In addition to *beatmatching*, a tool used to either speed up or slow down a record in order to match its BPM seamlessly with that of a previous track, DJs often refer to phrasing as one of the keys to successful performances. When Butler (2006) asked about what makes a great DJ, DJ Shiva referenced phrasing several times, suggesting that it involves aligning the larger formal divisions of each record in the mix:

> *"Anybody can string records together and learn to beat-match, but [..] a lot of people don't pay attention to composition, like how you phrase things […] when you're layering two records over each other, you layer the outro beats and the intro beats of the next song, and then the breaks all fall in the same spots. So it locks. As opposed to people who just throw on a record, and things are just happening willy-nilly all over the place, which sounds sloppy. And a lot of people still do that […] They're all like, "It's experimental." No it's not; it's just phrased badly"* (DJ Shiva, in Butler, 2006, p. 184-5).

Interestingly, phrasing can also relate to the coordination or synchronisation between musical lines. When Mark Butler (2006) continued to question DJ Shiva about what he refers to by phrasing, he replied:

> *"Just having them all lock in together, and mesh, instead of being all over the place. […] It's just like this [hand gesture indicating nonalignment] – they all sort of just drift instead of being locked on, basically"* (DJ Shiva, in Butler, 2006, p. 185).

Butler (2006) describes the importance of the structural form or shape of both individual tracks and complete DJ sets used in EDM, as directly affecting the music's 'intensity' or 'energy' level. He describes a prototypical form used in EDM, involving the same repertoire of formal sections: "intros, buildups (or builds), cores, breakdowns, and outros" (Butler, 2006, p. 223). Shaping a performance often involves manipulating texture, adding and dropping out various instruments, and repetitions of the 'core' with new, more intense elements. Importantly, the buildup is gradual and indistinguishable from the introduction or main 'core' sections, whereas the breakdown is clearly marked by a sudden, dramatic drop to a thin texture – dropping the beat. DJs by no means treat this organisation as a 'formula' (p. 224) – lengths of sections may vary – but there are certain 'unwritten rules' which guide the order in which sections appear. For example, the buildup always precedes the core, and a core never follows an introduction. "Thus the prototypical form described here is best understood not so much as a distinct formal structure as a recurring shape that embodies certain fundamental principles of construction and growth in EDM" (Butler, 2006, p. 225).

The shapes of these forms clearly resonate with the dynamic forms of experience evoked in Chapter 1. Just as a mother playfully introduces 'gotcha' to her infant at precisely the right moment, the climactic effect of 'dropping the beat' at the right time illustrates the skilled ways in which musicians too evoke emotion and life in their music by essentially shaping energy levels over time, directing the musical development in a manner which creates effective growth across an expansive time frame. Indeed, Malloch (1999) comments that the power of music depends on its ability to engage us in narrative forms of changing emotion, by expressing those forms in a manner universally appreciable to us.

The perception of form-level deviation

With respect to empirical investigation into the perception of musical timing at the form-level, Kuhn (1974) investigated the discrimination accuracy of professional musicians in identifying a modulation in beat tempo, by either increasing or decreasing the performed tempo or keeping it the same (Kuhn, 1974). 'Decrease' examples were correctly identified by musicians both sooner and more frequently than the other conditions (Kuhn, 1974). This finding is in keeping with performance data, which suggests that performance errors include primarily tempo increases – musicians tend to speed up in performance (Drake, 1968; Kuhn, 1974).

Recently, Honing (2006) showed that listeners were able to decide whether an audio recording was real or tempo-transformed (originally performed at another tempo, but made similar in overall tempo), purely on the basis of expressive timing judgments. Participants were asked to listen to pairs of audio samples from commercial recordings by well-known pianists, where one stimulus of the pair was an original recording and the other a manipulated, tempo-transformed recording of the same composition by another pianist. The task was then to judge which of the two performances was an original recording while focusing on the use of expressive timing – a task which most participants were able to do.

Apart from the perception of tempo and its changes, few studies have approached the analysis of the perception of musical form (Clarke, 1999). Indeed it is a difficult task to determine the perception of sectional proportions of a work, as the perception of form is constructed a posteriori (Cook, 1990). However, one study by Clarke and Krumhansl (1990) found a high level of agreement between musical and non-musical participants when they were required to segment a musical piece, in location, strength and structural characteristics of the formal boundaries. They also found that individuals were remarkably adept at identifying from where a musical segment has been taken in the overall layout of the music (Clarke & Krumhansl, 1990). Individuals are clearly perceiving both pulse-level and form-level elements of the musical soundscape.

3.3 Expressive timing in the digital realm

"Music exudes humanity; computer music exudes uniformity"

- (Bilmes, 1993, p. 58).

Several attempts have been made to model the expressive timing of a musical performance, with varying results (Clarke, 1987, 1999; Desain & Honing, 1994; Jensenius, Godøy & Wanderley, 2005; Maes, Leman, Lesaffre, Demey, & Moelants, 2010; Sundberg, 1988; Sundberg, Friberg & Bresin, 2003; Gabrielsson, 1999; Todd, 1989). For example, Friberg (1995) created a quantitative rule system whose purpose was to convert the mechanical performance of a written score into a 'musically acceptable' performance. Models of expressive timing have encouraged the use of tempo curves as an important factor in representing performance expression. However, others believe that tempo curves 'fall short' as the sole underlying representation of timing (Honing, 2001, p. 50). Instead, Honing (2001) proposes that mathematical modeling of performance expression should include both consideration for tempo variation (tempo curves) and the way individual notes are timed (time-shifts). But while musicologists are seeking to define and model the expressive qualities of performance, music-makers and producers in the electronic community are discussing the same kinds of notions: groove, swing, and feel (Bilmes, 1993; Progler, 1995). Since the birth of the digital age, people have been finding out how to make grooves and structural shapes work in a digitally-generated product (Keil, n.d.). Unfortunately, ethnomusicologists tend to treat these styles of music as being off limits (Keil, n.d.).

Some programmers have developed drum-machines and music sequencers to eliminate deviations or 'errors' in musical performance, and some extensively use the 'quantize' option in order to destroy those "flaws that make the performance sound sloppy" (Bilmes, 1993, p. 58). However, most computer-music makers prefer to exploit expressive deviation and call for the development of techniques that would enable computers to sound more "human" (Bilmes, 1993; Progler, 1995). Bilmes (1993) refers to the search for "expressivity, something more elusive, something that gives music its emotion, its feeling, its joy and sorrow, and its humanity" (Bilmes, 1993). One of the most successful designers and programmers of MIDI hardware and software is musician Michael Stewart, described as a leader in the trend to 'humanize' electronic and computer music (Progler, 1995). For example, Stewart's 'Human Clock' is a device that utilizes the natural deviations of a 'biological' drummer in order to make his music 'come alive' (1987). Stewart also created a general 'feel spectrum' which identifies different types of musical feels and proposes the amount of discrepancy needed to achieve the desired results using electronic instruments (see Figure 2 in section 4.2 below) (at 130bpm) (1987, p. 64).

One problem with investigating and modeling the nature of expressive music concerns the nature of the beat itself. In order to establish those 'extra bits' that are added to music to make it 'come alive', there is a need to define the structure or basis from which the deviations part. If the beat or pulse does exist in expressive musical performance, music programmes have not yet caught up with the human capacity to extract or infer it, and are far from doing so in real-time. "We know of no precise definition of beat for expressively performed music" (Dixon, 2001, p. 50). With a recorded performance in hand it is possible, albeit laborious, to transcribe the performance with enough detail to determine which notes have been performed on the beat. However, even with a transcription or score, it is currently impossible to associate score timing with recorded audio timing without error. Defining and identifying the beat is not only a concern for music programmers looking to create humanistic performances from electronic material, but also for researchers who are looking to describe the ways in which musicians 'deviate' from the beat itself.

In addition, there are often several notes associated with where the beat might be. When several instruments sound together, or when one instrument is responsible for creating two or more notes (piano chords, guitar chords etc), it is not obvious how the beat should then be defined. The notes of a chord are rarely played simultaneously (Palmer, 1997; Repp, 1992; Goebl, 2001), and the problem is aggravated in ensemble situations, where there are often systematic timing differences between performers (Keil, 1995; Prögler, 1995; Gabrielsson, 1999). In the case of several performers, should the beat be defined as the onset of the leader's note, or of the last person's note, or of the lowest, or the highest, or at the average of each note onset, or weighted toward one musician respective to another? What if each musician was purposefully placing their notes before the beat? Needless to say, there is no computer program nor iPhone application in today's market which convincingly 'hears' a beat in musical performance, quite like humans do. Only human musicians are able to convey meaningful expression through the subtle manipulation of time at both pulse and form levels, and musical listeners are intuitively picking up on this expression via temporal information available to them.

The previous section has explored the way musicians shape their temporal performances in classical Western genres, however, specific ways in which musicians spontaneously and naturally make music together are best studied through improvised performance. Gratier (2008) notes that the study of improvisatory musical genres points to different forms of meaningful temporal organisation, which relate to the social dynamics of playing together with other musicians. Though music with fixed notation is highly communicative, it is not *interactive* in the way that unwritten, improvisatory music is, as such music is "naturally in flux and reacts dynamically to listeners' and coperformers' unmediated sensorimotor involvement with it" (Gratier, 2008, p. 78). By studying improvisatory, creative-in-the-moment genres, a focus can be made instead on the interactive and intersubjective basis of musical expression in time (Reinholdsson, 1998).

3.4 Improvisation – Collaboration in real-time

"When you start to play off the top of your head, that's when the truth is really known about people".
(Guitarist Steve Howe, cited in Bailey, 1992, p. 41).

As one of the main objectives of this thesis was to consider musical meaning through the study of its processes and 'emergent' properties (Cook, 2001), a focus is made on improvisatory music-making in time. Improvisation involves a 'laying bare of one's soul': a willingness to open oneself to the vulnerabilities of expression in front of other individuals, and to do so in real time (Astin, 2010). Improvisation is not a new concept, in the time of Bach for example composition in real time was common practice (Duranti & Burell, 2004), and today some classical chamber groups are beginning to revisit this concept in their own musical performances (e.g. www.latitude37baroque.com). Many cultures improvise in different forms and in fact in all orally-transmitted traditions, improvisation is the norm rather than the exception (Lortat-Jacob, 1987).

The definition and meaning of improvisation has been extensively discussed (Ashley, 2009; Bailey, 1992; Becker, 2000; Berliner, 1994; Clarke, 1999; Duranti & Burrell, 2004; Hodson, 2007; Iyer, 2004; Lortat-Jacob, 1987; Nettl, 1974; Pressing, 1987; Sawyer, 2000; Sloboda, 1988). The main distinction between improvisation and composition in music is that performing a composition involves interpreting and articulating a written or memorized score, whereas improvising involves conceiving, articulating and remembering an unwritten, evolving score (Berliner, 1994). This means that while a mistaken note in a composition can be erased, a misplayed note in improvisation cannot. Iyer (2004) proposes an elegant definition of musical improvisation as "the in-time, temporally-extended exploratory interaction with the structure of one's acoustic, musical-formal, cultural, embodied, and situated environment" (Iyer, 2004, p. 165). This definition emphasises the temporally-situated nature of improvisation – performing 'on the spot' and 'in time'. In addition, we need to add that musical improvisation is also a reflection of essentially social processes: exploring musical material *interactively* and *collaboratively* with other musicians, as time unfolds before them.

Guitarist Derek Bailey has much to say about the nature of improvisation in music as well as several other performance arts (1992). The first point is that in order to research musical improvisation, formal technical analysis is simply not useful, both because it is impossible to transcribe it and simply insufficient in its description (Bailey, 1992). Any attempts made to transcribe performed music is usually into standard notation – involving strict conventions of how to represent pitch and rhythm. However, as Bailey (1992) describes, "most improvisation has scant regard for the niceties of the tempered scale, or for exactly uniform divisions of the 'bar' or beat. Attempts to show its 'deviations' usually take the form of arrows, dots, cent numbers, commas and all sorts of minute adjustments hopefully scattered through the standard notation system" (p. 15). Indeed, investigating communicative processes during improvisation is not a simple task, as controlled experimental conditions with analysis after-the-fact will always influence the creative impetus for the performance itself. Monson (1996) warns that improvisation is first and foremost a social process and should therefore be investigated in a naturalistic environment.

Secondly, because in improvisatory performance genres the musicians are much more responsive to the environment, the audience has a direct influence on the performance itself (Bailey, 1992). When the audience applauds or disapproves in the course of a performance, there is an immediate effect on the music-maker and therefore on the forming and choice of musical material used (Bailey, 1992). Jazz saxophone player Ronnie Scott talked about this special relationship with the audience, and expressed his view that the audience is in fact vital to musical meaning:

> *"You can't divorce playing this kind of music from the fact that there is an audience, you can't play it in a vacuum. It's got to be something that communicates otherwise it doesn't mean very much. I mean, you could sit in your front room and think you are playing fantastically and if there's no audience it doesn't mean anything"* (Ronnie Scott, cited in Bailey, 1992, p. 45).

Thirdly, improvisation involves a significant intuitive and spontaneous component. Learning to improvise therefore involves mostly practice as it has no purely theoretical aspect (Bailey, 1992). "Appreciating and understanding how improvisation works is achieved through the failures and successes involved in attempting to do it". (Bailey, 1992, p. 8). This implies that there are unwritten rules of how to improvise successfully with others which must be learned simply by performing and absorbing music with others.

There are several improvisatory genres worthy of investigation which might further our understanding of the experience of good time, including *cuadro flamenco* performance, North Indian musical performance, and various forms of blues, rock and other popular styles. However, because of my personal experience as an amateur jazz musician, having performed informally in several jazz groups, I have decided to focus on improvisatory jazz practices. In addition, the study of jazz is an especially pointed means for exploring the real-time, spontaneously interactive and creative processes involved in making music with good time. Furthermore, because of the social element involved in playing well in a jazz group, the study of jazz taps into our truly social, human communicative processes in time.

4 Jazz

The lack of scientific interest in psychological aspects of jazz music-making is surprising, as jazz musicians are clearly knowledgeable of "the almost imperceptible shadings of time that are critical to playing jazz" (Collier & Collier, 1996, p. 137). Those shadings of time with which jazz musicians are familiar are of particular interest in the search for *good time* in communicative, interactive settings. There are, however, two extensive ethnographic studies which have explored jazz practices to great effect. The first is Paul Berliner's (1994) "*Thinking in Jazz*", which details musicians' knowledge about the different stages involved in learning about and being socialized into the world of jazz. The second is Ingrid Monson's (1996) "*Saying Something*", which also explores musicians' knowledge and focuses on the often-overlooked rhythm section. These epic works will be referred to often in the following sections.

Jazz is a broad term, referring to 20-member big bands with detailed scores, unstructured 'free' jazz ensembles and intimate 4-piece groups alike, but the most well-known group format involves 4 or 5 members (quartets and quintets). Many people think of jazz improvisation as a group of musicians spontaneously and mystically 'making it up as they go', however the perceived freedom of jazz improvisation is often a myth (Berliner, 1994). Certainly, each unique performance emerges from jazz musicians' creative production in time, but musicians also have elaborate knowledge of the conventions and techniques with which they are to negotiate their joint activities. This is similar for many improvisatory practices, for example in the improvisatory performance genre *cuadro flamenco*, the feeling of spontaneity given off by the performance is only possible because of the existence of very strict codes and rules (Flores, 2010). A lot of the time, we may think that the musicians performing on stage before us have been together as a group for years and play together with what seems to be effortlessness. But in practice, jazz musicians are often called on short notice to perform with musicians with whom they have never worked (Becker, 1986), which implies that musicians must have common knowledge about the way they are to organise various aspects of their performances.

4.1 Musical conventions in jazz performance

There are numerous musical conventions jazz musicians share as common knowledge of the way to negotiate their joint activities in time. Many of these conventions in the culture of jazz have been described in great detail (Becker, 2000; Berliner, 1994; Gratier, 2008; Gridley, 1985; Monson, 1996), but a few will be outlined here, including playing a 'standard' within a traditional format of given rhythmic or harmonic structures, knowing about the roles of each group member and knowing the importance of listening to others. Importantly, conventions are not constraining, they are enabling: instead of making improvisational performances more structured or scripted, conventions enable performances to be more collaborative, improvised and emergent (Sawyer, 2003).

To coordinate their expressions in time, musicians rely on both tacit rules or conventions and mutually-agreed upon ones prior to performance. It is tacitly understood that musicians have common knowledge of the history and traditions of jazz practices, and acknowledge the musical etiquette into which they become socialized (Gratier, 2008). It is essential for example that jazz musicians be familiar with specific jazz styles, be able to recognise standard voicings and be 'well-versed' in specific variations. But the degree to which musicians talk together about their performances before they begin is highly variable (Gratier, 2008). They may decide to play a particular jazz tune with its own, predetermined melodic theme and rhythmic and tonal organisation, and in addition they may verbally agree on specific entrances and exits of musicians, or transitions between sections of the musical work. Clearly musicians discuss some aspects of their performance beforehand, and playing a specific musical work together typically involves players establishing at least the key they will play it in, and the rough tempo at which they will begin (Seddon, 2005). However, musicians tend not to discuss more subtle aspects of the music's temporal organisation, and importantly, these decisions determine only part of their behaviour – shared common knowledge about jazz principles and the work itself are the main resources for coordinating their activities.

Standards

Each jazz performance typically begins with some sort of song or theme agreed on in advance, then progresses to an improvisation, usually based on the initial song form, and usually ends with a reiteration of the song (Gridley, 1985). The most commonly-performed jazz songs are known as 'standards' and are based on themes of performances that have become classics: performances that are timeless and a reference point for other creative versions to come (Ashley, 2002).

Theme ---------------- Improvisation ---------------- Theme

The theme is usually structured with 32 bars of harmonic chord progression, divided into four sections of eight bars each (Berliner, 1994). There can be some confusion between a performance's *theme* and its *melody*. The *theme* (or chorus) refers to the overarching (or underlying) 32-bar harmonic chord progression, for example in the score further below (Figure 1), the theme stipulates that musicians play in A minor, then in Bb major etc for the extent of the 32-bar section. The *melody* (or tune) however refers to the melodic line a soloist will play on top of the theme – this is the line people tend to keep in their heads when the music is over. In a typical performance then, the rhythm section will play the theme during which a soloist will introduce the melody for the first 32 bars of music, and this is often called playing the 'head' or playing the melody 'straight' so that the audience can recognise the song. After the head, the group moves into a series of individual improvisations over the 32-bar theme. Following this, musicians are implicitly expected to know when the others have finished their solos, making sure all those who wanted to take a solo have done so, and then to seamlessly take up the reintroduction of the theme together (Becker, 2000). Importantly, such typical jazz arrangements are not meant to be taken literally by performers but are to be inflected in various ways according to well-understood conventions of given styles (Collier & Collier, 1996).

Individual roles, joint purpose

There are two subsets of the performing jazz group. There are those who constitute the 'soloists' or the 'frontline', involving brass, wind or string instruments, who contribute to playing the song's melody and soloing by improvising around the basic harmonic structure. And those who constitute the 'rhythm section', usually involving bass, drums and a piano or a chordal instrument (guitar, vibraphone), who create the rhythm which lies 'under' the soloists. Each soloist takes several repetitions of the chorus to perform their solo, allowing them to explore several musical ideas and elaborate on the melody. While a soloist is performing, the rhythm section's role is to improvise an 'accompaniment' based on the harmonic structure of the song, both 'supporting' and 'accompanying' the soloist (Berliner, 1994; Monson, 1996). When flamenco guitarist Paco Peña described his function of playing the accompaniment, he mentioned that his role was to 'encourage' or 'nourish' the full potential of the singer or dancer (cited in Bailey, 1992). This meant playing a good, clear rhythm and at the same time following 'whatever nuances' the other may bring to the performance (Paco Peña, cited in Bailey, 1992). But this does not imply that the soloist's performance is completely dominant over the others, there is a continual dialogue of ideas between all of the members of the group, which is probably the main reason why the term 'accompaniment' is used so sparingly and 'rhythm section' more often in typical jazz settings. It is in fact crucial to performance that each member of the ensemble is improvising simultaneously (Hodson, 2007): "the expressive processes involved in jazz performance are by *necessity* collaborative" (Gratier, 2008, p. 80).

There are complex tensions created between individual and collaborative or group levels of musical expression in jazz (Gratier, 2008; Monson, 1996). For many, the success of a performance depends largely on the creativity of its solos and might thus seem to be based primarily on individual expressing (Gratier, 2008). Certainly, one aesthetic of the music is centered on the inventiveness and uniqueness of individual solo expression, and it is important for jazz musicians to strive for unique musical identities and styles that define them (Duranti & Burrell, 2004). A separate objective for musicians is for them to produce 'climactic moments' of musical expression, which importantly "require the cohesiveness and participation of the entire ensemble" (Monson, 1996, p. 66). This leads to an inherent tension between the two, which is an important element in the development of the musical performance itself. In addition, because there are both soloist and rhythm sections in the ensemble, there are two levels on which the individual versus group tension operates: the relationship between the soloist and rhythm section, and between each individual to the others in the rhythm section (Monson, 1996).

Listening and tuning-in

In order to negotiate their way through emerging tensions in a jazz ensemble, most of the musicians Monson (1996) interviewed talked about the importance of listening in an *active* sense: saying that a performer 'doesn't listen' is a serious insult. Through active listening, musicians are able to initiate and anticipate musical opportunities, and repair musical errors (Gratier, 2008). "They must listen closely because they are continually called upon to respond and to participate in an ongoing flow of musical action" (Monson, 1996, p. 43). Listening and shared knowledge are intimately linked, as musicians are required to posses such knowledge so that they are able to listen for the common ground from which to create new musical material together (Gratier, 2008). A significant part of the way jazz musicians learn about structures and conventions of the domain is by listening (Sawyer, 2003). As a consequence, young or novice musicians often spend time listening to either renowned or favourite albums of jazz masters and playing along, trying to re-create the performance on their own instruments, note for note.

Part of what musicians are required to listen for involves a common musical repertory of licks, riffs and local habits. Licks are short melodic fragments, often used with variations, that come to define personal style and musical identity, whereas riffs are short repeated motifs that other musicians have used previously, taken directly from the history of jazz knowledge (Berliner, 1994). A knowledgeable musician will be able to identify a famous riff and anticipate its unfolding by hearing its first few notes. Riffs are in this respect a referential device (Gratier, 2008), referring to a musician's individual personality, style and performance history. Local habits involve a musician's knowledge of personal playing styles (Gratier, 2008). Jazz musicians must also be aware of the styles of the other musicians with whom they are playing, being able to anticipate their individual ways of combining of notes and sounds (Monson, 1996).

In addition, musicians must be aware of the way others *shape* musical sounds over time. Indeed, Imberty (1981, 2005) suggests that musical styles are not just musical ways of combining sounds into recognisable patterns, they are inherently time-based, personal ways of shaping time through patterns of tension and relaxation. Berliner (1994) makes reference to the importance of knowing different musicians' concepts, their 'vocabulary' patterns, their underlying logic for phrase construction and motive development, and their 'storytelling strategies'. Jazz pianist Sir Roland Hanna subtly refers to this when he talks about his relationship with bassist Richard Davis when they play together:

> *"I know he may be making a certain kind of passage. I've heard him enough to know how he makes his lines. So I may not know exactly what note he's going to play, but I know the general kind of statement he would make, or how he would use his words, you know, the order he would put his words is"* (Hanna, 1989, cited in Monson, 1996, p. 49).

Jazz musicians use many and varied metaphors to describe their memorable experiences in music-making, but often refer to a 'mutual tuning-in' (Schutz, 1967) or synchronisation with one another. Jazz trombonist Curtis Fuller says "when that's really happening in a band, the cohesiveness is unbelievable" (Berliner, 1994, p. 389) and according to trombonist Melba Liston, in these situations "you breathe together, you swell together, you just do everything together" (Berliner, 1994, p. 392). In contrast, *incompatible* styles are often referred to as a failure to *connect* (Sawyer, 2003).

Shaping jazz performances

Musicians must actively listen, tune-in and jointly negotiate their musical expression in time. One additional element of jazz performance involves creating dynamic shapes of intensity and excitement: musicians must also make a conscious effort to "direct" the music's energy (McBee, 1990, cited in Monson, 1996, p. 40), and to generate tension in order to make the music successful (Reinholdsson, 1998). Several of the musicians interviewed by Monson (1996) refer to the importance of shaping their performances:

> *"Climactic and then they reside. If you're constantly at one level it gets very boring, I would think. So it's almost like a preacher when he starts a sermon – he doesn't start with the climax; he starts with a little foreplay leading you to the subject"* (Davis, 1989, cited in Monson, 1996, p. 35).

There are different ways of achieving excitement in jazz performance, but jazz musicians consistently regulate various interrelated features of rhythm, harmonic colour and contour according to basic principles of tension and release (Berliner, 1994).

> *"Then there's certain ingredients that make you reach a certain level [of intensity]: repetition, change of octave, sometimes change of coloration of the notes, a repetitive phrase that catches on to something. You know, a musician doesn't talk about this too much, but it happens – because that's where it's at"* (Davis, 1989, cited in Monson, 1996, p. 38).

Just as Meyer (1956) introduced the idea that excitement in musical performance comes from manipulating our expectations, jazz musicians too must provide a subtle balance between variation and known material. Levitin (2006) talks about the way in which creative performances come from having just enough variation to keep the listener challenged, but not so much that it becomes difficult to follow. "The genius of [Stevie Wonder's drum-] playing is that he keeps us on our mental toes by changing aspects of the pattern every time he plays it, holding just enough of it the same to keep us grounded and oriented" (Levitin, 2006, p. 171). But it is a difficult task to respect the rules and structure of a particular piece, to express individual as well as collective style, and to create exciting and meaningful performances, all of this as the music unfolds in real time. How do jazz musicians time their productions so as to make them relevant for each other in the developing musical context?

4.2 Temporal conventions and techniques

Not only does jazz performance involve characteristic chords and harmonies, it also involves a myriad of rhythmic and timing techniques, more or less implicitly known to the player, and some believe that the temporal aspect of jazz is its most valuable. "Just as harmony is at the heart of classical music, so rhythm lies at the heart of jazz" (Collier & Collier, 1996, p. 137). Timing techniques serve a number of purposes, including, importantly, the conveyance of meaning to other musicians and to their audiences. Indeed, rhythmic subtleties in jazz can be said to operate at two distinct hierarchical levels: a 'compositional' one that emphasises motivic relationships and hierarchical structure, and an 'expressive' one that alters the microstructure of rhythm in smaller but important ways (Ashley, 2002). For classical musicians, there is less negotiation and greater consensus about what is permitted in terms of expressive timing – it is important to play similarly in order to express collectively those temporal nuances desired by the conductor or ensemble leader. In groove-based contexts such as jazz, however, much (if not most) of the musical output is negotiated in the course of musical play. Indeed in all live musical collaboration, the timing of an event depends not only on it's structural function, motoric or corporal constraints and the affective expression desired, but also on the moment-to-moment interpersonal negotiation of musical material (Gratier, 2008), including the beat itself. Therefore, within or in addition to expressive timing there must be timing effects which result from the social dynamics of playing together with other persons.

Jazz musicians have an implicit sense of the importance of temporal techniques for both expression and communication, using musical features such as structural markers and syncopation to delineate dynamic units for anticipation and projection (Gratier, 2008). To facilitate an understanding of the complexity of these temporal aspects of jazz performance, the following sections have again been divided into aspects at a form-level and a pulse-level.

Form-level temporal conventions

When musicians play jazz standards, they must know and understand the standard's form such that it becomes 'second nature', in order to coordinate their improvised performances within it (Hodson, 2007). The form of a song is effectively what keeps musicians 'in the right place at the right time'; indeed, 'keeping the form' is an important skill and musicians are often judged by their ability to do so (Hodson, 2007, p. 91). However, within the boundaries set up through form, each musician has a range of possibilities to which they are able to relate their individual improvisations (Hodson, 2007). By either explicitly marking out formal boundaries (conforming to form) or blurring those boundaries (deviating from it), musicians can emphasise or downplay the form itself. Interestingly, being flexible in their interpretation of form and obscuring metric structure is one way of creating 'suspense' in musical improvisation (Berliner, 1994, p. 329).

Rhythm section members are actively defining a song's phrase structure through the use of structural 'markers', for example by increasing or decreasing rhythmic density (Berliner, 1994) – identified easily in drummers' specialised one or two-bar fills just before the beginning of a new phrase. However, it is even more important for musicians to listen to fellow ensemble players in order to adapt to any changes of form that may come about over the course of a performance: a musician's choice of either emphasising or downplaying phrase structure depends principally on what other members are doing (Hodson, 2007). For example if one musician is strongly defining the form, another may either: follow the lead, further reinforcing the form; "relax into a more neutral definition" of form in order to establish balance; or "go along for the ride" – downplaying the boundaries in order to create a more fluid or relaxed performance (Hodson, 2007, p. 98).

Each soloist can improvise over one or more repetitions of the 32-bar chorus form, a section which can last for as long as the musicians have the inspiration or energy (or for as long as the audience stays attentive). Traditionally the musicians last to take a solo are the bassist, followed by the drummer, before the melody is reintroduced by one or more of the soloing instruments. The order of the soloing musicians and the lengths of their solo sections are two of several elements of a performance's overarching organization, even of a typical standard, which can be negotiated by the musicians together as the music progresses (Becker, 2000). Other ways in which jazz musicians can alter this organization involve playing introductory passages before or coda passages after the main part of the performance.

Another performance element decided on by the musicians as they play together and perhaps one of the most obvious examples for the audience of conversational exchange (Walker, 1994) is a technique called 'trading' 4s or 8s (or another small, even number of bars). This refers to a specific number of bars which are played successively by two soloing musicians (saxophone and trumpet, trumpet and drummer etc) – a standard procedure for exchanging short phrases among the musicians. Because each section is relatively short compared to the 32-bar thematic form, there is not quite enough time for each soloist to fully introduce and develop their own ideas, so each player 'trades' ideas with the other, responding to and building on material the previous soloist played (Berliner, 1994). A rough outline of the organisation of a typical jazz standard for a 5-piece ensemble, adapted from Walker's (1994) dissertation, is shown in Figure 1 below.

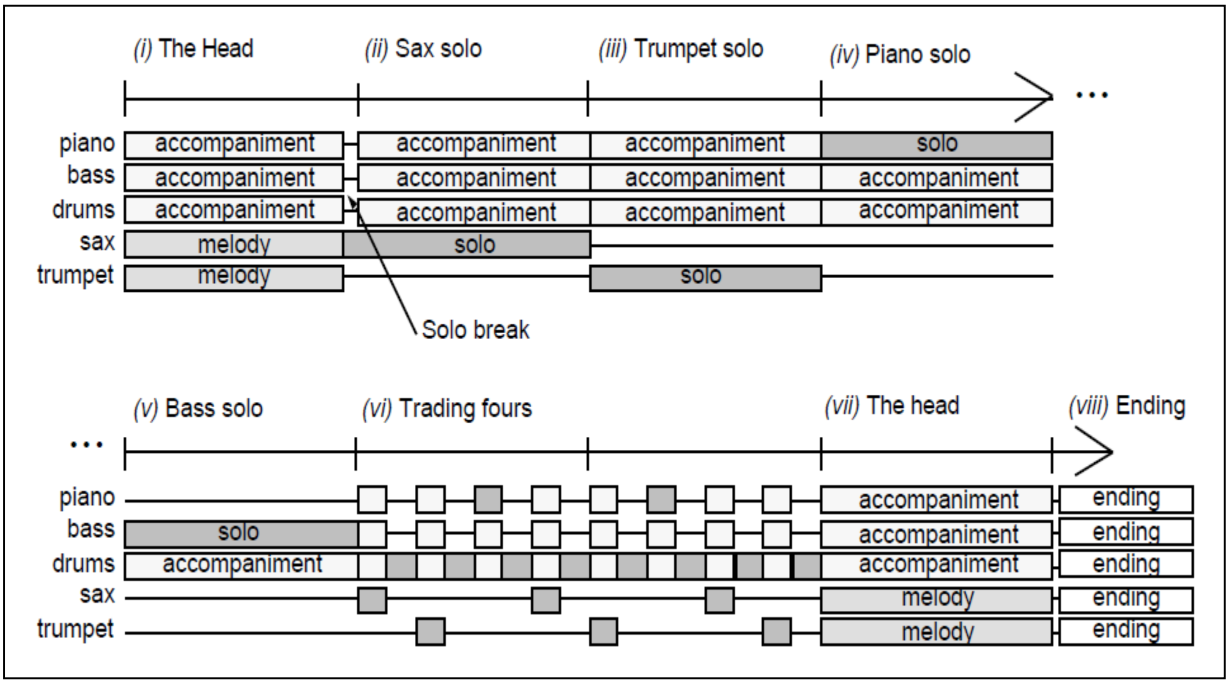


Figure 1: Timeline for one typical improvisation structure used by a performing group of 5 musicians. This organisation shows the Head or introduction of the melody, followed by three soloists' solos, followed by a rhythm section member's solo (the bass) followed by an uneven allocation of 'fours' traded between the drummer, the soloists and the pianist, followed by a reiteration of the Head and an ending. Image adapted from Walker's (1994) dissertation.

Again, playing a specific musical work typically involves players establishing the rough tempo at which they will begin. However, the nature of tempo over the course of jazz performance is often overlooked because groove-based genres such as jazz are generally considered to have a 'stable' tempo, relative to classical music (Busse, 2002; Iyer, 1998). Playing variations of a jazz tune are said to involve changes in the melody and only small changes to the harmonic organisation, but never involve varying the tempo: indeed tempo variation is known as 'not keeping time' and signaled 'serious incompetence' in musical play (Becker, 2000, p. 173). However, this is in contrast with musicians' discourse:

> *"All groups vary the tempo slightly through a performance, speeding up slightly as a solo builds to its climax, for example. Yet some musicians rush, others pull back, and some do both at different points in a song. Another problem with some musicians is that they play too much like a metronome, and they aren't able to subtly follow these tempo changes"* (Sawyer, 2003, p. 49).

Empirical investigation into the nature of tempo, however, has shown that across musical performances, slight but deliberate local tempo changes are common at specific moments to emphasize musical structure (Collier & Collier, 1994), by for example decelerating at the entrance of a particular soloist. This result is in keeping with Berliner's comments about the important interplay between inherent fluctuations of the tempo and the structural features of a piece (1994). On a larger scale however, Collier and Collier (1994) found that for 186 jazz recordings the final tempo varied by only 5% of the original, hinting at considerable tempo stability from beginning to end but missing the greater part of a piece's development. In addition, their study was based on previous recordings in which musicians may or may not have used a metronome during the recording process. The true nature of tempo over the course of a live, successful performance remains to be established.

Pulse-level temporal conventions

In order to investigate process-oriented activities such as playing jazz (Iyer, 2004), it is important to also focus on fine-grained rhythmic detail and temporal situatedness – investigating musical expression at the pulse level. Performers use several timing techniques at the pulse level to be both expressive and communicative in their musical play, including accents, accelerations, *ritardandi*, pauses and modulations of tension and relaxation (Iyer, 2002). *Syncopation* for example involves accenting notes that occur just before or just after a beat, establishing tension between the accent structure of the meter or underlying beat and the accent structure of the syncopated line, and *overlay* involves establishing a rival accent or phrase structure non-congruent with the dominant metrical structure, then returning to it (Iyer, 2002). Ashley (2002) sought to further investigate expressive timing at the level of a note or bar, and found various rhythmic procedures which related to musical structure. For example motivic structure was maintained and accentuated through the rhythmic changes: each motive had its own stylistically-appropriate rhythmic interpretation.

In addition to emphasising some notes with respect to others, jazz musicians inflect their performances with subtle temporal deviations with respect to the beat itself. Despite a musician's ability to strike, pluck or bow notes with great precision, even very small deviations have expressive importance (Reinholdsson, 1998). Bilmes (1993) mentions that performers 'hardly ever' play on the beat, but when they do, the time grid is explicitly defined but the performance sounds 'dead'. Jazz musicians are often discussing their music in relation to being 'ahead of the beat', 'behind the beat' and 'on top of the beat' (Collier & Collier, 1996). There are of course different sorts of attack for most instruments which also contribute to the timing of notes, but musicians are clearly in control of these instrumental effects and use them knowingly.

Jazz musicians displace individual notes or taps with great precision in several ways. For example, 'backbeat delay' refers to the way a drummer's snare drum beats on 2 and 4 tend to be delayed a fraction, giving rise to what musicians often call playing 'in the pocket' (Berliner, 1994). Iyer (2002) suggests that this may be a way of perceptually accenting these beats, as it involves the postponement of an expected consequent (Meyer, 1956). At the same time, soloists are said to tend to begin their melodies 'late' relative to the accompaniment, and speed up over the course of a musical phrase, known in the jazz community as 'back-phrasing' (Ashley, 2002). With regards to meter and harmony, Ashley (2002) found that harmonic notes occurring on a downbeat were displaced far more than non-harmonic notes occurring on the downbeat, a technique which he suggests may be used to manipulate musical tension (Ashley, 2002).

Swing

One major objective of jazz studies is to see if the ubiquitous phenomenon called 'swing' can be identified and described in detail (Collier & Collier, 1996). Many jazz musicians believe that swing is central to their music (Collier & Collier, 1996) and make studious attempts to break it down into its constituent parts. Swing can refer to a stylistic era within jazz or to the experience of a charged drive – music that is 'swinging' – which most closely resembles the notion of groove (Pressing, 2002). However, swing or the 'swing eighth' most commonly refers to the long-short rhythmic division of the quarter note – an ethereal technique that most would describe by clicking their fingers instead of using musical notation or words.

For some time, jazz students and aficionados alike have tried to ascertain the 'perfect' or 'ideal' duration ratio of long to short notes (onbeat:offbeat) relative to the tempo of the piece. Through examination of two Louis Armstrong solos, Collier and Collier (2002a) found that the swing eighth ratio is not, as is commonly thought, a 2:1 triplet, but ranges between a ratio of 1.4:1 and 1.7:1. However, Pressing (2002) emphasises that the ratio of these subdivisions varies systematically with tempo, such that it should be around 2:1 for tempi of 60-80bpm, with larger ratios at slower tempi and smaller ratios of around 1.3-1.6:1 for faster pieces. It is now generally understood that this ratio varies from one musician to another, and within the work of one (Collier & Collier, 2002a), in other words, researchers have not been able to capture those precise means by which musicians manipulate their swing to convey meaning to others. "Although many knowledgeable jazz people have made attempts at defining that magical quality, nobody has yet come up with a convincing definition of swing. It all depends, so it has appeared, on many subtle nuances of time and accentuation that are beyond calculation" (Collier & Collier, 1996, p. 117). What is certain is that metronomic accuracy and rhythmically isochronous time points or beats do not by any means guarantee swing (Schuller, 1989). Instead, Schuller's (1989) definition requires a beat, either explicitly or implicitly expressed, whose rhythmic impulses must be felt, not calculated, counted, or intellectually arrived at (1989, p. 223).

Solo versus rhythm section

An additional timing constraint in conventional jazz formations stipulates that setting up the framework and 'keeping time' are largely the responsibility of the rhythm section (Monson, 1996). There is a steady underlying beat provided by the rhythm section, to which the bass and drums or percussion contribute most clearly, and the piano or chorded instrument such as guitar contribute to a lesser extent. In relation to this framework, the other musicians play notes and rhythms variously suspended *around* the beat (Collier & Collier, 2002a). For example Ashley (2002), in his investigation of the nature of expressive timing, examined different recordings of the same jazz ballads. He found that jazz soloists extensively deviated from the underlying rhythmic framework, a phenomenon he describes as a kind of 'tempo rubato', involving flexibility in the temporal performance of melodic material over the steady, underlying beat of the rhythm section (in his study, the double bass' performance). But whether soloing musicians in jazz place their notes *on average* behind, ahead, or on the rhythm section's beat, and to what extent, has been of debate in recent research.

Friberg and Sundström (2002) found that soloists tend to lag behind the rhythm section's beat by about 50-80ms: the melody is mostly played after the accompaniment, opposite to classical music in which the melody 'leads'. This effect is clear in various jazz and groove-based genres by listening to the way a singer sings a little behind, 'dragging' on the beat (Ella Fitzgerald, Erykah Badu). Looking in closer detail at this relationship, Friberg and Sundström (2002) found that soloists' downbeats and offbeats were synchronised differently with the accompaniment – downbeat onsets were delayed and offbeat onsets tended to be closer or tighter. The authors suggest that instead of highlighting the soloist, delayed downbeats and synchronised off-beats may create both the impression of a laid-back soloist and the impression of good synchronisation (Friberg & Sundström, 2002). The timing between soloist and rhythm section musicians also appears to be related to tempo, as significantly greater delay was found at slower tempi (Friberg & Sundström, 2002).

In another study, Ellis (1991) investigated jazz saxophonist asynchrony relative to the beat, as defined by an artificial backing recording of piano and double bass. He found a strong tendency for the soloists to play behind the beat by around 40ms, an effect which also depended upon the tempo of the piece (here, the distance behind the beat increased with increasing tempo, from 40ms at 90bpm to roughly 60ms at 210bpm). Bilmes (1993), in another groove-based musical context, performed research on the timing discrepancies amongst the four performers of an Afro-Cuban Rumba group, and found that the lead and middle congas played around 30ms ahead, whereas the low conga played both ahead of and behind, each with respect to the clave, the instrument responsible for providing the reference beat.

It is now generally accepted (and jazz musicians have probably always intuitively known) that a soloist's timing relative to the beat is a complicated affair: instead of playing as squarely or closely to the beat as possible, gifted soloists tend to place their notes a little away from it, pushing in anticipation, dragging and lagging behind, or 'dancing' around the beat, anticipating some notes and delaying others. When soloists play too freely or fluidly around the framework, Monson (1996), in reference to the different roles of instruments and their relationship to timing, refers to the drummer being responsible for coordinating and nurturing other members of the ensemble by either pushing or restraining them with their own rhythms. Personal interactive timing style also comes into play: critics of Armstrong's style for example suggest that he played behind the beat, referring to his "slightly behind the beat rhythmic approach" (Gridley, 1985, p.7). Finally, the way in which soloing musicians place their notes in relation to the underlying beat (and the way in which they are encouraged to come back to it) also contributes to giving the music a certain quality or flavour: playing ahead of the beat called metaphorically 'snappy' or 'driving', and playing slightly after the beat lending the music a 'soulful' or 'laidback' feeling (Gridley, 1985).

Others have gone further in their description of how soloists should ideally play with respect to the underlying beat: Stewart (1987) for example has created a 'feel spectrum' – a formula which prescribes an assortment of timing 'feels' (Figure 2 below). From this prescription, according to Stewart, what creates *groove* should involve the soloing instruments playing between 5-10ms later than the rhythm section's beat framework.

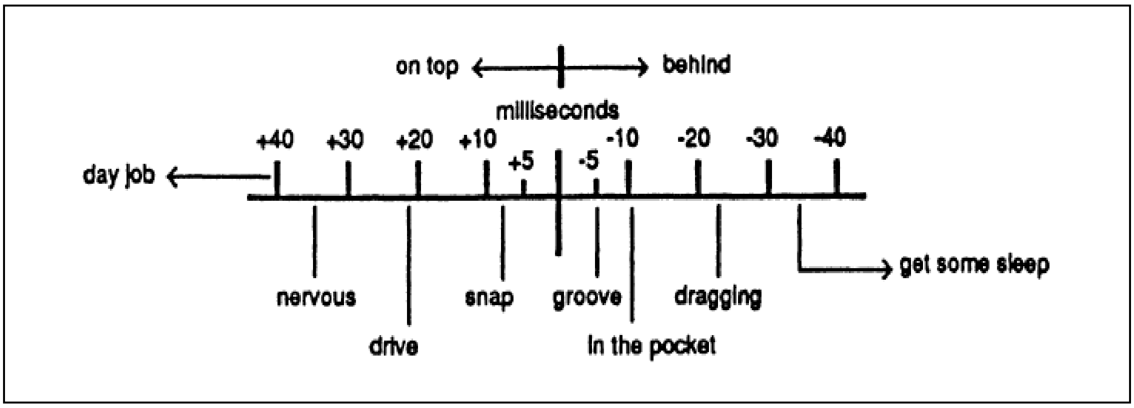


Figure 2: Michael Stewart's (1987) 'feel spectrum' prescribing different timing feels (at 130bpm), where a positive (+) represents notes played milliseconds before the beat, and a minus (-) to denote after.

5 What does it mean to play 'good time' in jazz?

5.1 Preliminary understandings of groove

Playing 'good time' is one way in which jazz musicians refer to the experience of groove, which is often considered as the most essential feature of successful performance (Madison, 2006).

While being groovy for some people may conjure up images of Austin Powers and flare-wearing beatniks, jazz musicians consider groove as a serious business. It refers to the sense of having a shared feel for the beat and for the possible futures of the unfolding musical performance; when 'in a groove', musicians are able to sense each others' movements and expressions, they sense how the tempo might progress and at the same time they anticipate harmonic progressions and melodic lines (Gratier, 2008).

Jazz musicians frequently describe the process by which they find a beat together and settle into the groove. It makes them feel tight musically and close personally, generating a sense of togetherness and intimacy (Monson, 1996). The musician Don Byron says grooving is "a kind of euphoria that comes from playing good time *with* somebody" (Monson, 1996, p.68, italics in original). By finding a groove musicians collectively produce a sense of time against which they converse and play, and this sense of time also possesses an emotional and interpersonal character. Another jazz musician, Phil Bowler, likens groove to a "mutual feeling of agreement" (Monson, 1996). What is important is that the groove is the result of musical and interpersonal negotiation between musicians. It does not come about by simply adhering to some common time signature: the common time feel of 'grooving' is collaboratively created and maintained through purposeful negotiation at various levels of musical timing.

Groove has been referred to by Charles Keil (1994) as 'engendered feeling', that certain something beyond notation that performers add to music to make it swing. However, Pressing (2002) defines groove as a firmly structured temporal matrix that can be contrasted with 'feel', which involves sensitive rhythmical nuance in note delivery, as in "he plays with a nice feel". These examples of groove definitions highlight two important points. Firstly, using the term groove tends to mystify the processes involved whereas they are in fact both embodied human and social collaborative processes, not purely musicological mystery. Secondly they reveal the dual meaning of groove, either as a culturally-determined musical matrix or set-up, such as the 'swing eighth feel' or 'rumba groove', or groove as the essence of a successful jazz performance. Butler (2006) agrees that groove can either be "a short configuration of bass line and percussion that unfolds in continuously repeating cycles" or "the way in which the rhythmic essence of a piece of music flows or unfolds" (p. 326). Of course the two are closely linked in jazz settings, but as psychologists we are more interested in groove as an experience, rather than the musicological reference to types of grooves. From here on I will refer exclusively to research and anecdotal evidence which considers groove as an experiential quality of successful jazz performance.

There is a close relationship between spontaneous motion and groove, as the presence of groove is often defined by the mere presence of motion (head-nod, feet-tap)(Iyer, 2002; Madison, 2006). Iyer (2002) defines groove as something which engages the 'walk' or locomotor channel of an individual's sensorimotor system giving rise to entrainment, and Madison (2006) operationally defined groove as "wanting to move some part of the body in relation to some aspect of the sound pattern" (p. 201). In addition, groove is often described by alluding to the quality of movement itself: "that quality that moves the song forward, the musical equivalent to a book that you can't put down. When a song has a good groove, it invites us into a sonic world that we don't want to leave" (Levitin, 2006, p. 170). Zbikowski (2004) concurs that musical meaning is related to the physical production of sound itself: "concepts like regularity, differentiation and cyclicity […] are a common ground where embodied and musical knowledge meet" (p. 278).

Furthermore, groove and sociability often go hand in hand: groove is like "walking down the street with someone" (Richard Davis and Kenny Washington, cited in Monson, 1996, p. 68). As there must be continual dialogue between each ensemble member, the groove is clearly a 'collaborative affair' (Gratier, 2008).

5.2 Striking a groove in the rhythm section

'Striking a groove' or creating the basic rhythmic 'hook-up' typically involves the drummer and the bassist synchronising together (Berliner, 1994; Monson, 1996). However, some believe that it is the role of the drummer to define the pulse, others believe it is largely the responsibility of the bassist.

A drummer's role is often said to involve the maintenance of a strong regular beat within the framework of conventional tempos and meters, which the bassist then plays around (Berliner, 1994). 'Playing time' or 'keeping time' is quite logically a particular specialty of drummers. Drummers do this by playing a periodic pattern often with a ride cymbal tap using their dominant limb, and this ride cymbal beat can be the most important component of a drummer's style, indeed, drummers can be characterised in terms of their cymbal beats: "[Billy Higgins] has a certain kind of feeling and he's got one of them big wide cymbal beats" (Kenny Washington, 1990, cited in Monson, 1996). Importantly, drummers must give one limb, often the cymbal, to the other band members, which becomes the 'solid', time-keeping limb, freeing other limbs to be more 'liquid'-like in relation to the time-keeper (Monson, 1996, p. 55). In addition, the drummer is said to have a coordinating and nurturing role, capable of influencing either soloist, bassist or pianist by pushing or restraining him or her with the playing of one or more limbs.

However, others believe that bassists are responsible for rhythmic stability (Collier & Collier, 1996), known for "laying down the time", and creating the "rhythmic-harmonic pulsative path" (Monson, 1996, p. 30). The bassist in fact has many roles and can alternate between them: holding time with the drummer (often using a walking bass line), initiating pedal points (holding a single pitch) or outlining the local harmonic progression, amongst others. When bass players initiate a pedal point, the drummer is said to be temporarily freed from coordinating with the walking bass and can play in a more soloistic manner (Monson, 1996, p. 34). On the other hand, bassists are also able to temporarily break from playing time or playing pedal points and respond to something coming from the soloist. To what extent drummers and bassists are accountable for the time-keeping is a delicate matter, but what is certain is that in the traditional jazz ensemble, both bass and drums *together* are most critically responsible for negotiating the beat and shaping the framework.

Little empirical research has investigated timing processes involved in the creation and maintenance of the beat around which other soloing musicians play – in the rhythm section itself. Reinholdsson (1998) explored expressive timing in the rhythm section using a previously-recorded 8-bar solo of drummer Roy Haynes. He first transcribed the solo by ear into musical notation, then compared the digitized version to a mechanically perfect one, and found that the range of deviations tended to be on the order of 5-30ms. In earlier informal work with bassists, Reinholdsson found that they were successfully able to play ahead or behind a beat produced by a metronome, as instructed. Friberg and Sundström (2002), using previous recordings with a range of tempos, measured inter-musician timing between the onsets of a bassist and a drummer's ride cymbal tap and found average differences of less than 20ms. This technique has the particular advantage of not assuming which instrument should be considered as playing the 'reference' beat, by simply measuring activity of one musician with respect to the other. Additionally, the bass was delayed relative to the drummer in all but one of the 21 averages (derived from Friberg and Sundström's figure 8., 2002, p. 343). This work suggests that good rhythm-section players purposefully either push the beat, play on the beat or lay behind it using very small deviations as they wish.

To return to Ashley's work (2002), in order to validate his use of the double bass' performance as a temporal grid against which to measure displacement from the soloists, Ashley firstly looked at the stability of the double bass' beat, inadvertently investigating microtiming in the rhythm section. He examined the changing tempi in the first 16 measures of each of three previously-recorded jazz performances, and found that mean tempo varied between 66.1 and 74.3bpm (12% increase). Each performance was clearly not metronomic – the standard deviations indicating that within each piece, there was slight give and take of the underlying beat – but was, he concludes, fairly consistent between performances (Ashley, 2002).

Richard Rose (1989) used jazz education recordings of Swing, jazz ballad and Latin jazz samples to investigate timing relationships among rhythm section instruments. By isolating different instruments in the samples, he found average local deviations in inter-musician timing or "mean latency values" of within approximately 20ms of one another, in which the drum-set usually led, followed by the piano, then the bass came last (Rose, 1989). Additionally, the musicians in his study tended to sustain beats 2 and 4 about 5% longer than beats 1 and 3 on average when playing a moderate swing groove with a tempo of about 132bpm (Rose, 1989, p. 77-84). But with respect to longer passages, in contrast to the elasticity of inter-onset intervals within measures, larger units such as eight-bar phrases were 'remarkably' consistent with one another (Rose, 1989). Prögler (1995) too, in his article titled 'Searching for Swing', investigated the most sought-after degree of displacement before or after the beat. Despite particularities in his methodology, Prögler's (1995) work is a rich description of microtiming features in the rhythm section, providing evidence for the effects of harmonic progression on the way musicians 'played' with the beat and evidence for different personal timing styles. For example in the same musical piece, one musician placed his notes most often 10-60ms before the beat, and another musician placed his notes most often 10-60ms after the beat (Prögler, 1995).

In several of these studies, researchers have used existing recordings, which can be problematic for distinguishing individual musicians' performances (tracks are fused together) and provides the researcher with highly engineered performances. A second weakness in the research is that attention is often paid to the mean local tempi or mean timing discrepancies between musicians, but the development or progression of such variables over the course of the musical work remains largely unknown. A third important methodological shortcoming of such studies is that researchers have focused on short musical excerpts, from which they generalise about groove-based music. But we know from musicians' reports that in live performance music does not always groove and that the quality of groove itself is variable. Research into the dynamic process of music-making in organic settings is needed if we are to investigate good time, that powerful engaging quality of music that comes about when musicians collaborate together, and feel that they are collaborating well.

An original perspective has highlighted expressive temporal coordination in jazz using a measure of 'synchrony' between two interacting musicians, defined as shared moments of peak intensity or loudness in the course of performance (Schögler, 2003). Through studying five duets of rhythm-section musicians recorded improvising together (combinations of drum kit, bass and guitar), pervasive cycles of synchronous expression were found, involving periods of low synchrony building up to periods of dense/intense interactional synchrony. Schögler (2003) revealed a larger, narrative-based level of variation in each of their performances, independent from musical structure and specific musician pairings. This novel approach demonstrates quantitatively the nature of 'shared control' in musical interaction, and highlights an additional influence on timing processes in the rhythm section – our natural propensity to shape musical sounds over time.

5.3 The nature of the rhythm section's beat

Another notion of good timing in jazz concerns the nature of the framework or beat provided by the rhythm section, of which there appear to be two trains of thought. One suggests that music with good time is the result of stability amongst rhythm section players, or the suppression of performer production variance (Pressing, 2002); a beat which is as strict, steady and isochronous as possible. Another suggests that the beat must be flexibly present.

An underlying near-isochronous pulse?

According to Iyer (2002), groove-based musics feature a structural framework which is steady, containing overall pulse isochrony: "a steady, virtually isochronous pulse that is established collectively by an interlocking composite of rhythmic entities" (p. 397). Rhythm section musicians themselves often talk of 'keeping time', and their role is often contrasted with the changing tempi (*rubati*) of classical music, in which everyone moves together in expressive waves. Pressing (2002) asserts that music with groove is the result of a firmly structured temporal matrix, with a metronomic approach to timing: equal pulse durations and a stable tempo. For Monson (1996), "groove supplies underlying solidity and cohesiveness to freely interacting, improvising musicians" (p. 67). In addition, the framework must be sure and steady so as to inspire confidence in the other players, as well as strong and infectious so as to induce movement (to make you want to tap your feet)(Monson, 1996). Berliner too notes that many musicians discuss striking a groove in terms of 'precision' and 'being tight' (1994).

In Pressing's (2002) epic account of 'Black Atlantic Rhythms' and their psychobiological foundations, he presents the hypothesis that rhythms purportedly stem from our evolved cognitive talent for the formation and use of predictive models of events. Specifically, rhythm arises from the capacity to predict the timing of an event (or note) expected to occur in the future. Situations in which timing becomes highly predictable should be those with 'ready perceptibility' and 'consistency in production' (Pressing, 2002). In other words, this expectancy hypothesis will best be suited to a musical context with a "regular isochronous stream of rapid-onset events" or an "evenly paced time marking" (Pressing, 2002, p. 295). Accordingly, elements which make it difficult to predict temporal placement would include loss of attention, lapses of memory, and an instable tempo for example. Pressing (2002) then suggests that groove is effectively a way of minimizing those factors which limit expectation accuracy. This is because groove is arousing (engaging attention), stimulates movement (encouraging acoustic and muscular memory) and the combination of a stable tempo with a regularly divided pulse provides a reliable framework for greater prediction accuracy.

According to Butterfield (2010), the effectiveness of a soloist's expressive timing depends on the coherence and consistency of a well defined beat in the rhythm section. When bass and drums widen the temporal gap between their onsets they are compromising the effectiveness of a soloist's use of participatory discrepancies. "The narrower the attentional focus around well defined peaks of expectation, the narrower is the span of what will be perceived as 'on time' and the greater the salience of any expressive deviation perceived as 'early' or 'late' (Butterfield, 2010, p. 169). Butterfield (2010) then talks about how this presents a fundamental execution problem in particular when a soloist who is trying to time melodic eighth notes against the rhythm section's quarter-note pulse: "When you have different guys in the rhythm section playing on different parts of the beat," laments trumpeter Jimmy Robinson, "they're going to be fighting each other constantly, and it's very difficult to solo against that" (Berliner, 1994, p. 413). For Butterfield (2010) then, an underlying, near-isochronous pulse contributes to highly efficient anticipatory attending.

In order for the beat to be steady, there must be congruence between each musician's conception of timing: each participant must have shared or at least compatible representations of timing and accentuation in order to successfully shape the framework together (Pressing, 2002). But do the musicians who establish this beat indeed always strive to play precisely together?

Playing with the beat?

Other researchers (and sometimes the same ones) make reference to *shaping the framework* and *shaping the groove*, and highlight variability instead of stability amongst rhythm section players. Berliner's musicians mention the collective maintenance of the beat as involving 'subtle nuances' (1994). Schögler (1999) notes that in order for musicians to play together in time, they must be aware of a common pulse, but specifies that pulse in this sense is not the isochronous timekeeper, but is modifiable by experience, sensitive and amenable to change. The framework must be reliable enough for others to anticipate their activity with respect to it but is, by necessity, variable.

Monson (1996) also implies that drummers and bassists do not always aim to play perfectly together when she talks about drummers compensating for bassists, adjusting their playing according to whether the bassist is playing 'on top of' (before) or 'behind' the beat. Keil (1994) notes that almost all drummers and bassists are known amongst themselves for either being 'on-top' or 'lay-back' players and that what works well and what can often be seen in historical jazz rhythm section combos are complementary or compatible duos of one of each type of player. However, others say that this simplifies the problem, categorising individual musicians into one of two groups, while bassists and drummers can in fact change and adapt their manner of playing in relation to the beat (Hodson, 2007). Rather, the beat should be relatively flexible, one that 'breathes', against which bassist and drummer vary their onset timings in order to drive the groove (Butterfield, 2010; Hodson, 2007). Iyer (2002) defines all groove-based musics including jazz as those which give rise to the *perception* of a steady pulse in a musical performance, but which also involve subtle microtiming deviations from rigid regularity and shows that in such contexts fine-scale rhythmic delivery becomes just as important as tone, pitch or loudness.

Some of the most detailed research into what makes music 'groove' comes from the work of musician and musicologist Charles Keil (1987; 1994; 1995). Keil systematically analysed bass players' and drummers' placement of notes and beats in time, determined that they did not always play entirely together, and that these slightly perceptible deviations from unison were in fact deliberate components of their musical play. Keil then called these deviations 'participatory discrepancies' (PDs) in the rhythm section, and suggested that it is *because of* the discrepancies or deviations from perfect timing inherent in musical play that music acquires groove and becomes interesting. "Music, to be personally involving and socially valuable, must be 'out of time'" (Keil, 1987, p. 275). Others agree that players 'enliven' their music by minutely varying the placement of pitches in relation to the beat (Berliner, 1994). Progler (1995) also shares Keil's contention that it is the *gaps*, large or small, which provide the push or layback feel of a particular performance, after he found himself that drum and bass attacks were rarely on the beat, instead falling either before or after that beat. "Rather than playing *with* the beat, some performers were *playing* with the beat (Progler, 1995, p. 48, emphasis in original). Levitin (2006) too agrees that groove works best when it is not strictly metronomic, when it is not perfectly "machine-like" (p. 171) and adds that groove most often comes from the drummer's skill at manipulating constant fluxes of tempi. "The gold standard of groove is usually a drummer who changes the tempo slightly according to aesthetic and emotional nuances of the music" (Levitin, 2006, p. 172).

This apparent debate between the musical worthiness of stability and isochrony versus variability and elasticity in the rhythm section merits further investigation. Importantly, although deliberate and controlled, Keil (1994) mentions that musicians were not necessarily fully conscious of what they were doing to establish this groove. Must rhythm section members play steadily and precisely together, in order that soloing musicians be freely expressive around them, or must they play with variability in order for the music to groove?

Both stability and flexibility

Berliner (1994) suggests that for many musicians a critical element of making music with groove involves the synchronization between drummer and bassist, discussed often in terms of 'precision', 'unison', and being 'tight', but at the same time, he notes that musicians convey a 'world' of subtle nuances. Monson (1996) suggests there may be some flexibility in the jazz rhythm section, "but the primary function of the rhythm section is nevertheless to provide the timeline against which the soloist can interact and build" (p. 83). It may be then that some aspects of musical expression are reflective of stability and others of flexibility, or that they each move through periods of stability and flexibility over the course of the musical work. For McGuinness (2005), groove describes the rhythmic feel of music with both a stable global tempo, and with systematic microtiming deviations. Drummer Jimmy Gomes had also seriously been considering the meaning of swing and groove:

> *"In his thirty or so years of tapping a ride cymbal, he arrived at a paradigm for rhythm section performances that revolves around a pendulum concept. For example, in a rhythm section of three elements - bass, drums and piano - Gomes hears them as falling into a groove with one being a bit ahead, one being a bit behind, and a third swinging like a pendulum back and forth between the two extremities"* (Progler, 1995).

Importantly, as jazz improvisation involves essentially social processes, the ability to anticipate and participate is more than a function of where the beat lies at any given time. Instead, playing with good time must also come from the history of musicians' interactions, their continually-updated common knowledge set, their recognition of each other's familiar passages and shapes in performance, and "their ability to actively deploy sound to affect each other's musical behaviour" (Monson, 1995, p. 88). Jazz musicians often talk of instant musical connections they have formed with other musicians (Berliner, 1994), and refer to this empathetic attunement as an important means for 'striking a groove' together. "Spontaneous, fortuitous moments of coming together or hooking up are highly prized by musicians" (Monson, 1996, p. 143).

The way a musician places their sounds and movements in time relates crucially to what other members of the ensemble are doing, and whether he or she wants to follow the others, when to complement and support the others, or remain 'grounded' and keep time in a more inflexible way. Jazz drummer Ralph Peterson (quoted in Monson, 1995) talks about this in relation to bass players, but the same notion likely applies to all of the other members of the ensemble.

> *"Another thing about bass players that's very important is their ability to concentrate when I or another member of the ensemble moves away from the basic pulse beat – and start playing against the time, if you will. It's not always the best idea [..] when somebody else starts playing against the time – to hear that and go with them, because somebody has to stay grounded [..] When a bass player has the [..] wisdom to know when to [..] play against the time and leave me as the centrepoint, that's very important"* (Peterson, 1989, quoted in Monson, 1996, p. 174–5).

Monson (1996) herself takes up this notion in reference to solid and liquid time. According to her, solid time is the relatively stable element against which a soloing musician can express even more off-beat ideas, and "the stronger the time feel, the easier it is for a soloist to take risks" (Monson, 1996, p. 28).

Finally, the quality of groove or performance with good time may not simply be a result of either stable or flexible elements, as it appears to be related to the unfolding shape of the temporal interaction itself. Monson (1996) hints at this when she remarks that the quality of groove is a result of dynamic tensions between fixed and variable elements of an ensemble. The over-arching coherence and shape of one of the musical works studied in detail further suggests to her that "interactive musical participation creates something larger than local interactive exchanges in terms of both musical shape and human bonds" (p. 189). Along similar lines, Benzon (2001) has recently described a *groove stream*, as a kind of collectively-managed temporal framework, within which musicians are able to enact their dramatic, gestural, individual expression, and still be together in time (2001). The gestural content to which he refers is said to be analogous to the contours of melodic narrative development (Benzon, 2001), taking as its basis the concept of Clynes' *essentic forms* (1977).

5.4 How musicians and outsiders hear music with groove

Jazz musicians are obviously skilled orchestrators of their movements in time, and verbal reports from musicians themselves suggest that they are also perfectly capable of listening out for micro-temporal rhythmic subtleties. For example when a bassist was shown to weave around the metronome, playing temporally before and after it, another musician noticed this after the recording's playback when he said, "that last bass player was messin' with the time all over the place" (Prögler, 1995, p. 33). By the same token, when bassist Sabu Adeyola was asked to play along with a metronome, afterwards he shook his head with a smile and said, "that dude don't wanna move" (Prögler's interviews, 1995). Jazz musicians are remarkably self-reflective of their performance practices, partly because there is no external goal other than the process of their performance (Sawyer, 2003).

However, there are many dimensions of improvisation that performers are unaware of, which suggests that interviews of musicians and their insights cannot be sufficient means for investigation. In addition, despite jazz musicians' knowledge and control of musical timing, they are not always in agreement about how these processes should work, about how to create good time. When musicians play together, both performers and audiences feel that sometimes the music grooves well, and that sometimes it does not; sometimes the music is 'laid-back', sometimes 'pushing' onwards, and sometimes the musicians are just not quite 'in sync together'. Good time is not necessarily present in all musical play: younger or novice musicians struggle to find their own grooves and groove together – it is a skill sought after – which means that one can learn to groove, but it is not generally the result of direct instruction (Friberg & Sundström, 2002). What is the nature of this shared and implicit know-how? How do musicians coordinate their individual ideas and purposefully negotiate their joint musical productions with *good time*?

In classical genres, studies have illustrated that measurable stylistic performer differences are also measureable in the perceptual realm – they are heard and can be rated by expert musicians. Expressive micro-timing is clearly perceived in classical performance, and to a certain extent an outsider prefers and possibly expects to hear such variation in musical play, but the perception of micro-timing variation in jazz performance has received little attention.

We, the audience at jazz performances, may think we are also highly adept at listening out for temporal accuracy, freely celebrating moments of temporal technical skill and critiquing moments when two musicians are not quite 'listening to each other'. The jazz listener may think they know what sounds intuitively natural and musical, but how are they able to do this, and do they know how or are they perceiving unwittingly? What is it about pulse and rhythm that makes musical performance sound 'coordinated' and interesting? 'Outsiders' – people with no direct training of specific jazz principles – certainly know even less about why it is that music has or does not have 'good time', and how two musicians might negotiate this quality together. They probably do not appreciate to the same extent different subtleties of timing and how for example instrumental roles and culturally-based personal styles come into play. Instead they appreciate simply that musicians are highly skilled and know how to play perfectly together – which is true, but the skill has also been shown to involve knowing how *not* to play together.

There have been few experimental studies investigating the perception of micro-timing variation in jazz performance. In one study, Busse (2002) modelled live piano performance variations using a complex 'groove quantize' system and applied them to MIDI data. His rule system measured 3 variables from the performances: note placement relative to metronome, note duration and note velocity in several one-measure samples, which were subsequently averaged across performances to obtain a general measure of the way individuals produced their music with 'groove'. The 'groove quantize' option subsequently applied these variations to either real or synthetically-created MIDI performances, after which experts (42 jazz performers and educators) rated the examples in terms of swing 'style' or 'swing representativeness' using a Likert scale from 1 - 6 (least to most representative). Similar to Bilmes' (1993) results, Busse (2002) found that experts preferred both the original (unaltered) melodies and derived performance model variations (with the real performance groove quantize option added) to mechanical performance models (constructed from mathematical ratios). Albeit an in-depth investigation of the way individual pianists produce different groove styles (on average), the study does not measure directly the quantities of timing discrepancies heard.

To date, Butterfield (2010) has been one exception, performing an investigation of the extent to which asynchronies performed between two jazz instrumentalists can be perceived. Butterfield (2010) argued that even if smaller discrepancies are not perceived, it does not mean that their *effects* are not experienced; if it is the temporal gaps which provide the 'push' or 'layback' feel of a particular performance, then listeners should be able to identify "not so much the gaps themselves as their effects in terms of the push or layback feel they are thought to produce" (p. 158). He then investigated an individual's perception of small timing differences (10, 20 and 30ms) between the performed notes of drums and bass, by asking participants to say whether the drummer or bassist was temporally 'leading' and to choose which version contained more 'assertiveness'. His results showed that participants were not able to successfully discriminate between bass or drum leads nor determine which instrument was more assertive, which suggested to him that non-musicians are neither able to hear the effects of nor the actual asynchronies involved in musical contexts (Butterfield, 2010).

Butterfield then claims this result as evidence that asynchronous timing between bass and drums in jazz is not exclusively or even predominantly responsible for generating the engaging rhythmic quality known as swing or groove. Instead of the more flexible beat of the theory of participatory discrepancies (Keil, 1987), Butterfield (2010) concludes that the central value in jazz timekeeping is not a beat that 'breathes', but simultaneity between bass and drums in their maintenance of a rigorously steady pulse, without perceptible deviations from isochrony. However Butterfield's (2010) task demands were relatively complex for such small differences: rather than a simple discrimination task, subjects were required to both perceive differences and identify which of the two instruments was leading the other, which in turn involved deciding which instrument lead *most* of the time, as the percentage of time each instrument was actually leading ranged from 60.5% to 91%. In addition, it may be that these differences are too small to be utilised for decisions of temporal order, whereas judgments of the extent of temporal asynchrony would be a very different cognitive task. Finally, it may be that musical 'effects' manifest themselves in much simpler ways than 'assertiveness' – plausibly, one performance may simply sound more 'coordinated' or 'successful' than another.

Further studies are clearly needed to investigate the extent to which untrained subjects can hear such participatory asynchronies in live musical performance.

6 In Summary

In summary, there have been several studies investigating both the production and the perception of musical play with good time, each of which has been summarised in the following tables (Tables 2 & 3 below). These studies indicate that much is known about the quality of expressive timing in classical genres, but fewer studies have investigated subtle aspects of timing in jazz.

Studies on musical time in jazz have tended to focus on swing and the magical ratio of triplets, but there has been some interest in the microtiming subtleties of interaction between musicians, and in particular the rhythm section, in which musicians are thought to be responsible for driving the groove together. In addition, music is communal: it cannot function without sharing and without communication. As jazz involves the ever-present element of sociability and morality in performance, investigation into the timing of jazz musician interaction should reveal more fundamentally human and social processes involved in the joint creation of musical meaning, which may operate at different levels of pulse (moment-to-moment) and/or form (overarching structure).

The Production of Timing in Musical Performance						
Authors	**Music Sample**	**Tempo changes**	**Inter-musician timing**	**Concerning which instruments?**	**Direction**	
					Ahead	**Behind**
Ashley (2002)	5 versions of commercial jazz recordings (first 16 bars)	Between versions: 8-12%* Within versions (SD as % of tempo): 0.7–4.2%	Range = -400-800ms	Solo (Trumpet) Vs Referent (Bass)	Both	Both
				Solo (Tenor Sax) Vs Referent (Bass)	Referent	Solo
Bilmes (1993)	Live recordings with separate tracks, 6 afro-cuban percussion songs		Average = 30ms	Solo (Lead & Middle Congas) Vs Referent (Clave)	Referent	Solos
				Solo (Low Conga) Vs Referent (Clave)	Both	Both
Collier & Collier (1994)	186 performances, commercial jazz recordings	Within & between versions: < 5% (4, 8 & 16-bar lengths)	-			
Ellis (1991)	Live recordings, MIDI saxophone with computer-generated bass		Range = 40-63ms*	Solo (MIDI Sax) Vs Referent (Computer Bass)	Referent	Solo
Friberg & Sundström (2002)	6 commercial recordings, 10-26s excerpts	Within versions: 3-16%	Range = -25 - 120ms* Average = -20 - 80ms*	Solo (Various) Vs Referent (Bass&Drums)	Onbeats: Referent	Solo
					Offbeats: Both	Both
Progler (1995)	Live recording sessions and one play-along record	(metronome)	Range = 4-80ms*	Drums Vs Bass (sometimes same player)	Both	Both
Reinholdsson (1987)	An 8-bar Roy Haynes solo		Range = 5-30ms	Drums Vs Referent (Transcription)	Both	Both
Rose (1989)	3 commercial recordings, 'Play-along' records with separate tracks	'Stable' (8-bar lengths)	Range: drums= lowest SD; piano = highest SD Average = 6-35ms	Drums Vs Piano Vs Bass	Drums Piano	Bass

Table 2: Summary of studies on the production of timing in musical performance. Figures with an asterisk (*) were calculated using tables from their publications.

The Perception of Timing in Musical Performance				
Authors	**Music Sample**	**Instrument**	**Methods**	**Results**
Bilmes (1993)	resynthesised recordings – afro-cuban percussion	computer tones of conga and clave	*Preference choice between*: Quantised + original deviations vs Quantised + random deviations vs Quantised + no deviations	→ preferred →'sloppy/random' → 'mechanical'
Busse (2002)	resynthesised recordings – jazz	MIDI piano	*Stylistic ratings of :* Original melodies vs Derived performance model 'groove' deviations vs Mathematic performance model deviations	} more like jazz swing → less like jazz swing
Butterfield (2010)	synthetic recordings & commercial recordings – jazz	drums and bass	1. *Which instrument leads?* Bass & drums asynchrony varied between 10-30ms. *Or which instrument sounds more assertive?* Or both listening strategies. 2. *Identify leading instrument*	→ Participants barely answered over chance. → A few participants performed better.
Clarke (1993)	synthesised (computer) samples – classical	MIDI piano	*Imitate:* Rhythmically perturbed vs Rhythmically natural	Easier to imitate natural rhythm
Hirsch (1959)	non-musical context	computer tones	1. Differentiate 2 tone onsets (JND) 2. Perceive order of 2 tone onsets	→ minimum 2ms → min. 10-20ms
Repp (1992)	synthesised (computer) 'deadpan' samples – classical	synthesised piano	*Discriminate note that changed:* One note's duration was altered from mechanically perfect at different structural positions.	Perception dependent on musical structure
Vernon (1937)	– classical	recorded piano	Differentiate 2 tone onsets (JND)	minimum 10ms

Table 3: Summary of studies on the perception of timing in musical performance.

4

Introduction to the Research

1 Rationale for the Studies

This thesis aims to create links between the existing ethnographic work on jazz, and psychological studies of the temporal constraints and potentials of the biological, social body – in the hope of gaining further insight into real-time, embodied musical communication between performing musicians. Research on the processes and meanings involved when two musicians play well together in time have been reviewed within three interdisciplinary areas: at the level of natural, biological rhythms of the mind and body; at the level of social, collaborative influences on our behaviour with other individuals; and at the level of musical conventions and aesthetic principles which guide live improvisatory performance.

1.1 Biological Time

The literature presented in Chapter 1 has revealed several important points. Firstly, though perfect synchrony with a regular beat is challenging, studies have demonstrated that under certain conditions humans can synchronise with a metronome with almost no error (Aschersleben, 2003). However, it is not a natural behaviour to tap perfectly in time with a metronome: when subjects are free to produce their own rhythmic pulse they demonstrate spontaneous variation (Semjen, Vorberg and Schulze, 2000). There is some indication then that being 'in time' with another individual should incorporate natural variation or fluctuation, and predicting and synchronising with the movements of other 'error'-producing humans must be even more challenging. Despite this difficulty, recent behavioural research has indicated that it might be easier and the preference of individuals to synchronise with variable rather than isochronous events (Himberg, 2006; Kirschner & Tomasello, 2009). In addition, slightly out-of-time social entrainment is experienced more positively than either tightly coordinated or totally uncoordinated engagements (Warner et al., 1987).

In musical contexts, there is no perfectly isochronous beat, no completely objective acoustic stability to listen out for and play along with (unless playing against an electronic recording). In this sense musicians are not entraining to a pulse, rather they spontaneously create a sense of pulse as they coordinate their bodies and intentions with others' movements around them (Schögler, 2002). The theory of communicative musicality has provided great insight into the human potential for coordination in time (Malloch & Trevarthen, 2009). Humans possess an innate motivation to communicate with others from our first few breaths and this communication is principally enabled through interpersonal synchronisation – becoming tuned-in to the sense of time of another.

In order to achieve this tuning-in, interaction partners need to adjust their internal states to each other and accommodate for the natural tendency to be slightly 'out of' time. However, empirical evidence on time production and perception is not often considered with respect to interpersonal, social dynamics, even if a significant part of everyday behaviour is dedicated to being in time with other human individuals. At a deeper level, there appears to be an intellectually driven separation between the research areas of communication in relation to an *individual's* perception and construction of meaning, and communication in relation to *interpersonal* meaning construction or social-level, cultural meaningfulness (Moran, 2007).

1.2 Social Time

The capacity for sharing thoughts in time also relies on a common awareness of body-related time and space that affords representation in mimetic form (Donald, 1999). Individuals must construct a shared time-space around a common pulse with inherent variability (Schögler, 2002), yet this coordination occurs *collaboratively*. Social togetherness – the process of 'getting in sync' with other social individuals – surely must include the moment-to-moment interpersonal negotiation of musical material including the tempo and the beat itself. In this sense, part of this thesis' objective was to further strengthen the bridge between social and individual levels of meaning, by investigating the concept of being together in time in settings with two or more moving and thinking individuals.

Scholarly perspectives and methods for the study of social communication over the last century have focused overwhelmingly on language. Music is certainly a means for communication, but empirical studies of musical cognition and perception have mainly considered this communication in the same way as language or propositionally-structured communication, involving statement and reaction, turn-taking, call and response (Moran, 2007). Meanwhile, musicians are busy jointly coordinating and negotiating their performances *at the same time* – as one musician 'responds' to an idea of another, the other may be simultaneously evoking a new idea of his own. There is a dirth of methodological tools available for such action-based analysis of the interactive nature of musical collaboration. Moran (2007) suggests we take into account the active use of language in real contexts, in the vein of the performative linguistics of Austin (1962), and consider that musical communication is rather like language in the sense of being used "to create and maintain social relations through joint actions which sustain communicative events" (p. 6).

The theory of communicative musicality has demonstrated that the study of non-verbal communication – everything other than said words and sentences – can tell us a lot more about our natural drive to communicate. Jazz has been described as 'staged communication' (Imberty, 2005), but in this thesis we are not directly concerned with those overt linguistic or symbolic cues that musicians use to communicate with each other, such as winks, thumbs up, or saying "that sounds good". Instead, there are subtle yet tangible means by which musicians communicate together – through the skilled manipulation of their sounds and movements in time. Surely, there are many musical allusions and personal jokes that are for the eyes and ears only of the musicians playing together, or for the privileged few who know the musicians or are particular concentrated and well-versed themselves in jazz culture and history. But one of the most crucial aspects of musical exchange is appreciated by all audiences, novice or expert – that is, the experience of *good time.* Music is created in time, and musical meaning must refer to an experience of time, generated through real-time acts of perception and interaction (Moran, 2007).

1.3 Musical Time

An infant's sympathetic motivation for sharing cross-modal gestures and expression in time demonstrates core temporal skills (Malloch & Trevarthen, 2009), which themselves have led to the cultural artistry manifested in Beethoven's music or in blues, trip-hop, reggae, jazz, drum 'n' bass, lullabies, action-songs and many more musical genres. The literature presented in Chapter 3 attempted to establish some of the culture-specific musical rules which influence the way musicians play together and perceive their joint productions with good time.

Firstly, it was shown that discrepancies between performance and notation constitute an essential part of musical communication (Sundberg, 1988), of which the subtle manipulation of rhythm is critical (Schögler, 2002). In electronic music production, composers strive to model humanistic expression or divergence from mechanical flatness and precision (Bilmes, 1993). In addition, there is substantial evidence to suggest that much of the feeling and meaning in music comes precisely from those discrepancies or deviations from mechanistic performances (Bengtsson & Gabrielsson, 1977; Collier & Collier, 1996; Juslin & Madison, 1999; Laukka & Gabrielsson, 2000; Meyer, 1956; Palmer, 1989; Repp, 1998c; Seashore, 1938; Schögler, 2002; Todd, 1985), and relies on larger-scale dynamic 'feeling forms' of tension and release (Langer, 1942), a direct reflection of the ebb and flow of human emotions themselves.

Musicians, in order to play together in time, must be aware of both the dynamics of musical deviations (pulse-level) and feeling forms (form-level). There have been several studies investigating the production and the perception of good timing, at both pulse- and form- levels of musical play. Many have emphasised the importance of expressive timing and focused their investigation in classical genres, but fewer studies have investigated subtle aspects of timing in genres in which social communication is paramount. Secondly, timing research is rarely conducted in rich, live musical contexts. Yet live performance is the ideal context in which to study timing, because it provides a situation in which both performing musicians and audiences are regularly commenting on timing and on its success or failure. It is all too common to hear comments such as "this group plays really good time" or "those musicians sound like they're completely in sync".

This is particularly the case for improvised duets from the groove-based tradition of jazz. Jazz musicians are clearly knowledgeable of "the almost imperceptible shadings of time that are critical to playing jazz" (Collier & Collier, 1996, p. 137), and a duet involves unavoidable in-time communication and negotiation between each musical player. A jazz duet can be comparable to the communicative dyads observed in the study of adult conversation and in mother-infant 'proto-conversations' (Lee & Schögler, 2009), as each communicative partner is intimately involved in shaping time. Studies on musical time in jazz have tended to focus on swing and the magical ratio of triplets, but there has been some interest in the subtleties of temporal interaction *between* musicians (Keil, 1994), and in particular in the rhythm section, where musicians are thought to be responsible for driving the groove together (Prögler, 1995; Reinholdsson, 1987; Rose, 1989).

Musical meaning is also mediated by the embodied actions of performing musicians (Moran, 2007): our actions are grounded in the abilities of our bodies to do what we would like them to do (at the same time our bodies are always escaping us and doing things just before we think them, that is why we think through our body's actions and take possession of them often retroactively). However, in both studies of classical and groove-based genres, little attempt has been made to link findings with general properties of human temporal production and perception. For example, the pervasive 'melody lead' in classical performance has not been mentioned in relation to the finding that humans tend to time their movements *in general* a little ahead of the beat. Importantly, the knowledge that individuals delicately shape their actions over time has been rarely addressed in a musical context – there has been little attempt to investigate subtle aspects of time over lengthy sections or the totality of a musical work.

More importantly, studies on expressive microtiming have focused almost exclusively on timing discrepancies used to individually express something about the meaning of the musical piece (Clarke, 1999), ignoring communicative, interpersonal subtleties of timing in an ensemble. What about timing that is used to communicate something, such as "*I like what you're playing*"? As jazz involves the ever-present element of sociability and morality in performance (Duranti & Burrell, 2004), investigation into the timing of jazz musician interaction should reveal more fundamentally human and social processes involved in the joint creation of musical meaning.

2 Methodological Issues & Strengths

There are many and varied sources of apprehension for studying timing in jazz, several of which were introduced in Keil's dialogue on studying groove (n.d.). Specific methodological issues relevant for each of the three studies presented in this thesis are to be found in their corresponding chapters – here only those general issues which are relevant for all three studies are presented.

2.1 Studying live musical process

Much of the work within music psychology and musicology compares performance timing with notation (Repp, 1990; Sloboda, 1985). Notation is an integral part of analysis, but it does not deal very well with sub-syntactical microtiming (Prögler, 1995), those deviations from notation that impart music with good time and groove. Secondly, comparing performance with text does not take into account the processes involved in musical creation and collaboration. This does not mean to say that researchers should ignore the products of musical creation, simply that textual accounts of how the music 'should' be played – an idealized plan of action – are of little use in improvisatory settings. Any musical analysis must examine both the traces (the product) and processes that led to their creation (Nattiez, 1990). Instead, one of the ways to consider musical timing is to work with the material, acoustic trace of performance – a longitudinal plot of sound production can be used as an improvisation's musical 'score'. And rather than performing uniquely musicological analyses, there is a need to also consider the biological, cultural and interpersonal context in which the music-making took place.

One source of apprehension comes from using the word 'discrepancies', which tends to invoke the idea that musicians are somehow mistaken or not entirely in control. Furthermore, what musicians think and say about their practices does not always align with what is measured (Palmer, 1989), which can imply that not only are musicians making mistakes, they are talking mistakenly about their own practices. However, musicians are very much in control of their sounds and movements to precision within milliseconds. In order to investigate the experience of being in a communicative exchange with good time, it is important to include the study of both pulse-level and form-level scales of temporal organisation. The theory of communicative musicality has shown that humans instinctively communicate by coordinating and shaping their interaction together within both shorter (pulse) and longer (narrative) time-spans (Malloch & Trevarthen, 2009). Furthermore, musicological analyses have shown that musical expression is heard and projected both in the moment, and over the length of a musical work: the temporal contouring of expressive intentions is purposeful through both microtiming and macro-temporal shapes (Imberty, 1979; 1981).

2.2 Stepping into the mysterious world of jazz

Music psychologists can be skeptical about entering into the established world of jazz, as studying musical participation in such a genre can seem too "mysterious, illogical, paradoxical, touchy-feely, religious, new age, irrational, romantic, Rousseauian, essentialist, and so forth" (Keil, n.d., p. 2-3). But the ethnographic studies of Monson (1996) and Berliner (1994) have shown us that the experience of playing good time together is a real, engaging quality of music that comes about when musicians collaborate together, and feel that they are collaborating well.

There is a significant vacancy for research in live (natural) and improvisational (highly communicative) settings. In several of the studies cited, researchers have used existing recordings, which can be problematic for distinguishing individual musicians' performances (tracks are fused together) and provides the researcher with highly engineered performances. In fact most analyses of jazz microtiming have been performed either using commercial recordings, or in controlled experimental situations using MIDI. Controlled experimental conditions with analysis after-the-fact will always influence the creative impetus for improvisation. Improvisation is first and foremost a social process and should therefore be investigated in a naturalistic environment (Monson, 1996). Investigating musicians' communicative processes while they are improvising therefore requires organic settings, in which the researcher can observe the situation avoiding interference to how or what musicians are playing on any level.

A related concern comes from the fact that musicians are often referring to their performances in terms of playing ahead, behind or 'on top of' the beat, which leads us to wonder whether the beat actually exists if noone admits to playing 'it'. Nevertheless, musicians' notes have to be measured in comparison to something (Bilmes, 1993; Collier & Collier, 1996). Several researchers have adopted a position in which notes are measured against the framework provided by the rhythm section or some sort of reference beat (e.g. Ashley, 2002). However, rhythm section musicians are also actively shaping the musical performance, and the beat itself is not a metronomic, measurable event, it is a felt, perceptual construct inferred from the music (Iyer, 1998). One simple solution is to measure musicians' activities with respect to one another, providing a measure of timing relative to other music-makers, rather than to some abstraction of the musical 'ideal'.

2.3 Studying the variable nature of joint, creative activity

Another source of apprehension comes from the notion that measuring, with precision, such rich musical data can be too reductionist and scientific a method, in a sense an insult to the real complexity of the ongoing musical process. Musicians can be, understandably, skeptical of those who reduce the subtle shapes and colours of their music into biological tendencies and generalisations. On the other hand, I believe that ignoring a musician's art as a window into the skilful perfection of temporal creation would be even more regretful. One respectful gesture is to consider that all musical activity is a reflection of personality, style, and variable human affect. This implies that instead of examining a few select bars of musical output, the whole musical work or exchange must be considered. Music happens in time or in the moment, but music also exists across time, which means that musical meaning can be derived from both moment-to-moment events and exchanges, and from the dynamic development across time of those events and exchanges.

Thus, one of the methodological issues was to consider just how to explore extended periods of dynamic interaction between two living, meaning-making individuals. The idea of studying individuals *over time* in their natural environments forms the foundation of ecological psychology (Barker, 1968; Gibson, 1979), and others too have been urging scientists to put time back into their consideration of experience (Stern, 2000). However, the intensive observation of people over time results in a formidable amount of data, and as time becomes an inherent structural component of the dataset, it goes from two dimensions of variability (persons and variables) to three dimensions (persons, variables, and time).

An important methodological shortcoming of many studies is the lack of research into the dynamics of musical participation over time: attention is often paid to the mean local tempi or mean timing discrepancies between musicians, but the development or progression of such variables over the course of the musical work rests largely unknown. In improvisatory settings, researchers have focused on short musical excerpts, from which they generalise about groove-based music. But we know from report-based studies that in live performance music does not always groove and that the quality of the groove itself is variable.

For these reasons, an ecological approach – studying the variability of musical behaviour over time in humanly-shaped environments – has been chosen. Indeed one of the key elements of this thesis was to consider the experience of being together in time with respect to its dynamic development. By employing an ecological approach, particular temporal processes are revealed, such as cycles or rhythms, involving duration, growth, return to baseline, and that which involve co-variation of change, either at the same time (co-occurrence) or across time (lagged-co-variation). Through the study of live musical performances, plotted against real-time axes, insight may be gained into the temporal processes of coordination and negotiation, upon which collaborative meaning-making is based. Furthermore, these processes are akin to the dynamic temporal forms of tension and release described in European tonal music and which some musicologists and psychologists are sensitive to (Imberty, 2005).

Lastly, research into the dynamic processes involved in making music with good time cannot ignore what musicians consider to mean 'being together in time'. One of the direct consequences of this statement is that I have begun each investigation by approaching the music-makers about their performances – musicians' discourse is an essential element to this work – then proceeded to investigate the material, acoustic traces of their musical productions.

3 Research Questions

General Aim:

The general aim of this work was to further understand the experience of being together in time, and to investigate how the collaborative process of meaningful music-making reflects this experience. The general objectives of this thesis were to search for acoustic indices of the process and experience of playing 'good time' together in live jazz performance. Live jazz performance was chosen as representative of an ecological situation involving direct communication and negotiation between individuals and because jazz musicians are particular specialists in mastering good time between them.

Specific Aims:

This research considers that playing good time is essentially an experience, involved with the process of playing together with another moving, thinking individual. A review of ethnographic literature describing this experience has underlined a disagreement between whether good time is a function of stability or of flexibility. One of the aims of this thesis is therefore to clarify this disagreement: to further understand whether the experience involves temporal stability, flexibility, or a combination of both. A second aim of this thesis is to establish at which levels of musical timing flexibility and stability apply. Is the experience of good time dependent on moment-to-moment timing – the level of pulse – or is it rather dependent on longer spans of over-arching temporal shaping – the level of narrative? At each level, either flexibility or stability or both may be important in the co-construction of meaningful musical expression.

Three research questions have been formulated to guide this investigation:

1) How might the experience of good time contribute to the organisation of musical improvisation?

2) How do the sound productions of two rhythm section musicians reflect the process and experience of playing good time together?

3) How do outsiders hear 'good time' in musical performance?

Each question was then approached in each of three separate studies, outlined below. The first study consisted of a largely descriptive analysis of freely improvised jazz duet performances, filmed and annotated by one of the musicians as well as myself. This study aimed to describe the structure and negotiation of the emergence of moments of good time. The second study involved a quantitative analysis of jazz rhythm section performance based on an acoustic microanalysis of pulse and a macro-analysis of co-constructed form in 4 versions of a song. The third study involved a series of experiments on the perception of inter-musician timing by 'outsiders', exploring how musically-untrained subjects experience the sound of being 'in' and 'out of' time in manipulated musical samples.

4 Introduction to the Studies

4.1 STUDY 1:
A descriptive analysis of freely improvised jazz duet performances:
Playing 'good time' and 'saying something'

Where, and how, in the course of a musical improvisation, does 'good time' emerge, as determined by the performing musicians themselves? Secondly, how do the musicians structure or shape their 'free' performance? The aim of this study is to gain an overview of the dynamic development of musicians' exchanges with respect to their experience of good time. It essentially involved a descriptive analysis of two musicians' live free improvisations together recorded over three days, to explore the ways in which their efforts and interests for musical and intersubjective communication are patterned and sequenced in their expression through their use of sound and movement in time. A focus was placed on what music analysts refer to as large-scale development of live musical performance, in addition to the processes by which the structure emerges. Three specific research questions were formulated to guide this investigation:

1) How do the musicians structure or shape their 'free' performance? Is this structuring or shaping similar on the 3 days?

2) Are there identifiable moments or periods in which the musicians agree that they are playing 'good time', i.e. that they are communicating well through musical sound? How do these moments or periods emerge and disappear?

3) What is the relation between the narrative shaping of the piece as a whole and the moments/periods of good time between the musicians?

Musicians were interviewed to ask about their performance practices and their impressions of the improvisations recorded for this study. Episodes of the musicians' interaction were then delimited by searching for transitions, defined as moments of rest between episodes of musical intensification. Both of the musicians then identified these transitions themselves as they listened retrospectively to their performances. Secondly, pulsed and non-pulsed sections were delimited in order to explore how the musicians used timing at the pulse level, and whether this would contribute to a sense of good timing between them. In addition, for each narrative episode delimited by two transitions, one of the musicians (the guitarist) was invited to describe their improvisations in detail with a specific notion in mind – the experience of good timing. Finally, an attempt was made to link the basic felt structure of improvisation (the organisation of narrative episodes) with the presence of pulse and with the emergence of an experience of good timing.

4.2 STUDY 2:
An acoustic analysis of jazz rhythm section performance:
Negotiating pulse and form together in time

The objective of this study was to explore, in further detail, the acoustic basis of playing 'good time' together in jazz. As the nature of the recordings made of musicians' improvisations in the first study did not permit the separate study of each musicians' acoustic contribution, this study was drawn up principally to investigate recordings with separate tracks, in order to explore musicians' coordination and negotiation *between* them. As timing is a particular specialty of rhythm section members – often said to be responsible for driving the groove – the opportunity was taken to study a situation in which the temporal success of the rhythm section was brought to the foreground.

Four versions of a musical composition performed by a jazz quartet for the recording of a studio album were obtained, in which two rhythm section players (bassist and drummer) openly disagreed about the success of two of the four versions, and in the course of the argument the musicians repeatedly referred to problems with timing. The third version was unanimously rejected by the group and the last version was accepted by all the musicians and their producer as the 'keeper'. What is the musical evidence of differences between successful and unsuccessful versions? If musicians are able to feel implicitly that on one occasion the music works and on another it does not, we should be able to observe objective differences between them.

The aim of this study was to seek evidence, based on acoustic analyses of the musical tracks, that in the third version the rhythm section players were not able to maintain a sense of playing 'good time'. This study then takes a situation familiar to any professional musician involved with 'making music', as a starting point for an empirical investigation into the timing processes underlying the experience of good time. The aim was to focus on those aspects of timing that are negotiated in the course of musical play – the development of collaborative and communicative ensemble timing – rather than on the more frequently studied phenomenon of 'expressive' timing at the individual level. The acoustic analyses in this study focused on temporal negotiation at the pulse level and provided measures of local tempo, inter-musician timing and musical activity.

4.3 STUDY 3:
Experimental studies in the perception of inter-musician timing:
The sound of being 'in' and 'out of' time

The first two studies focus on performance characteristics, how musicians produce a musical work together. But there is also the mirror to performance: how listeners perceive the music, or rather create their perception of the work. Audiences are also skilled perceivers of musical timing (whether they have formal musical training or not) – highly adept at listening out for temporal accuracy, celebrating moments of temporal technical skill and critiquing moments when two musicians are not quite 'in sync together'. The audience is also involved in the collective experience of groove in musical performance, and theoretically musicians are always communicating something to their audiences, whether they are present or merely imagined. This study asked whether outsiders – people with no formal musical training and no specific knowledge of jazz practices – can hear when two musicians believe they are playing 'good time' together, and when they are 'out of time'. In order to investigate the perception of good time, I manipulated the temporal contingency between the separate tracks of drummer and double-bass player in a naturalistic musical sample. If a musician's experience of good time is related to the timing between them, the question was asked whether this inter-musician timing would be perceived by outsiders, and to what extent.

In Experiment 1 I investigated the way outsiders perceive the quantities and placement of inter-musician timing in live jazz collaboration. Several temporal conditions of manipulated inter-musician timing were created (perfect temporal synchrony between players, naturalistic, imperfect asynchrony, or other forms of inter-musician timing) and participants' preferences and judgments were recorded. In Experiment 2 I asked participants about the range of inter-musician asynchrony which they considered to be acceptable. Its aim was to determine the just noticeable difference between music with and without perceived 'good timing' between musicians. Are outsiders capable of indicating at what point they believe two musicians to be 'in time' and 'out of time'?

5

A descriptive analysis of freely improvised jazz duet performances: Playing 'good time' and 'saying something'

This chapter investigates how two jazz musicians create and negotiate musical meaning with good time through their embodied and audible exchanges. The study takes up the first research question posed in this thesis, namely, how the experience of good time might contribute to the organisation of musical improvisation. In other words, is good timing pervasive throughout performance or do musicians slip in and out of good time throughout their interaction?

A descriptive analysis of video recordings is presented of two professional jazz musicians, a guitarist and a drummer (Misja Fitzgerald Michel (MFM) and Christophe Lavergne (CL)), who have known each other for many years and have performed together regularly in various contexts. The two musicians were invited to freely improvise together in a rehearsal studio rented for the study over half a day during 3 consecutive days and without prior discussion as to what they would play. At the time of the recordings, the two musicians had not played together for some months and had no short or long term musical projects. The musicians were then interviewed on a semi-formal basis, and asked to describe each of the recordings with respect to their experience of good timing between them. As this study was principally a qualitative exploration of the ways in which two musicians engage in musical meaning making in a jazz environment, the following introduction contains several notions introduced by the musicians themselves. In my analyses of the recordings of this duet over the 3-day period, I have focused essentially on what music analysts would traditionally refer to as large-scale development and what communicative musicality theorists refer to as musical narrative.

1 Introduction

What processes are involved when two musicians – two friends who know each other well – are playing *good time* together in a relaxed, improvisatory environment? MFM comments that it can be a 'kind of telepathy', and certainly a first impression of the skilful and intuitive interaction between musicians would lead many to assume that such processes are simply inexplicable. But groove or good time is not pure musicological mystery, it is a tangible experience evoked in the music performer and listener alike, and researchers should therefore be able to study its acoustic basis. Playing music with good time and *saying something* – evoking musical meaning – is what Kühl (2008) terms the 'semantic' aspect of music: strong, meaningful reactions in the music listener evoked by an auditory stream of structured sound.

When musicians rehearse or jam around a standard tune common to their repertories, their musical play is, to a certain extent, implicitly structured over time. Musicians know approximately how long they will play the 'head' (introducing the melody), then how long a soloist is going to play their solo (roughly based on a number of repetitions of the head), then how long they will play the melody again at the end. They know this because they have common knowledge of the way the standard was originally played and of how other musicians each played their versions of it afterwards. There is also a common understanding that standards, of a particular era, style and composer, are generally played according to specific conventions that structure the temporal organisation of the performance. But when musicians improvise by going into a jam-session or performance without discussing any particular standard or extended chordal arrangement to play, the temporal structure of their performances must be negotiated by the musicians in time, collaboratively, to a greater extent.

Within different improvisational practices, both CL and MFM distinguished between 'free' improvisation and more 'common' improvisational settings. Musicians who perform 'free' improvisation typically do not discuss any musical element to be used in their performance, whereas more 'common' improvisatory set-ups typically involve one or more of the melodic instruments deciding (either before or during the performance) at least what chordal progression, general tempo or harmonic feel the music will have. Mendonça and William (2004) propose that a jazz standard may afford more opportunities for divergent thinking than a free improvisation, as their performance enables the improviser to spend less time trying to determine the structure and content of the tune itself. However, the boundaries between the two practices are often blurred – some 'free' musicians occasionally discuss which chord to use or gravitate towards one harmonic feel in their performance, and 'common' improvisational settings can involve sections of 'free' musical play. Pushing the boundaries between improvisational styles is certainly not new for jazz musicians, as the main *objective* of improvising, for some musicians, is to challenge norms and break away from conventional melodic, harmonic or temporal expectations.

But whether musicians are improvising freely or adhering to musical guidelines, they are nevertheless negotiating various additional aspects of their music in time as they seek expressive and meaningful performances. For example, the overall organisation of musical improvisations must also involve the dynamic negotiation of different musical styles. Respecting one other's musical style and demonstrating their respect in performance is paramount (Monson, 1996). Gratier (2008) has shown that the process of making music together regularly involves establishing a 'common ground' between various musical styles and conventions employed in performance. It is clear that establishing common ground can be an important element in particular for musicians who have not or have rarely performed together previously. But establishing common ground can also apply to musicians who perform together often, as an individual's knowledge of cultural conventions and styles is continually being updated. Furthermore, musical culture itself is constantly being negotiated and adapted by both performers and listeners of that culture (Gratier, 2008). Monson (1996) comments that some musicians can come to know and anticipate others' moves to a certain extent, but only after years of performing regularly together.

Yet even in highly stylised or rehearsed performances, basic physiological and deeply-rooted aesthetic constraints contribute to shape the way musicians play together over time. To cite the most obvious constraint, it would be a musical marathon to play for 5 hours without rest, and in contrast, playing for too short a period of time – say 5 minutes – would be an unsatisfying performance for both performers and listeners. Between these two extremes, literature pertaining to human biology provides additional clues. Humans are under the influence of cycles of wakefulness that typically last around 90 minutes, including periods of reduced attention, heightened attention and back again (Dahl, 1996).

Furthermore, the theory of communicative musicality proposes that, from birth, humans possess an innate ability to coordinate their behaviours in time and a propensity for sharing meaningful narratives with others (Malloch & Trevarthen, 2009). We are essentially born with the instinctive impulse to enter into exchanges with other human beings through rhythmic forms, melodic variations and dynamic surges of sound and movement. These exchanges have been described as occurring at three interdependent levels: pulse, quality and narrative (Malloch, 1999; Trevarthen, 1999). The pulse of communicative exchange refers to the way we use our voices and body movements to establish expectations indicating to partners when the next event will occur. The dynamic evolution of the pulse is an important tool for rendering musicians' exchanges with expression (Malloch & Trevarthen, 2009). The quality of an exchange refers to the way in which individuals modulate their voice's timbre and melodic contours to communicate with others – the musical dimension of which is the musical phrase (Gratier, 2008; 2010). Finally, narrative refers to the way in which pulse and quality are organised into cyces of shared interest and excitement through time (Malloch & Trevarthen, 2009), involving the repetition of phrases into series which serve to create tension, growing from a point of origin to its climax and then its end.

These processes, often studied in the communicative exchanges of mothers and infants, have recently been likened to those of two improvising musicians shaping time together (Lee & Schögler, 2009). Indeed, such patterns of tension and relaxation are a defining characteristic of most musics, structuring them with narrative (Imberty, 2005). The length of typical narrative episodes in mother-infant communication have been identified as between approximately 10 and 30 seconds (Malloch & Trevarthen, 2009), which, in combination, contribute to larger 'extended narratives' in musical, theatrical and other artistic domains of story-telling (Osborne, 2009), and might be related to recent research on extended working memory in cognitive processes (Ericsson & Kintsch, 1995; Snyder, 2000). Importantly, such an emphasis on the ways individuals structure their communicative exchanges shows that meaning does not primarily come from the content of the message conveyed, but through the means by which the message is delivered (Stern, 1985). Furthermore, some underline that the most important communicative element is the moment when the resolution occurs (Imberty, 2005; Stern, 2000).

In Mukherjee's (2008) recent description of therapeutic, musical exchanges between herself and children with autism spectrum disorders, she defines 'episodes' of interaction as "significant components of engagement in musical companionship" (p. 300). In each of the episodes she observed, there was a deliberate act to initiate the interaction, an interactive development using an exchange of expressions, a climax, and finally a resolution, in which both partners were satisfied that they had shared each other's feelings and intentions, which in turn incited new motives to extend the engagement or to initiate a new episode of interaction.

In reference to creating a successful performance, both musicians in this study referred to a similar quality when they talked about the 'architecture of the set', involving both the length and temporal organisation of a performance. MFM comments that what the audience wants to hear and what they appreciate listening to are important factors to take into consideration when structuring a musical performance. For example, it is particularly relevant to him not to give listeners an "overload of information", as most audiences cannot 'handle' more than roughly 50 minutes to 1 hour of musical performance at a time. This becomes an issue when the owner of the club or concert hall in which the performance occurs requires the group to play for a certain length of time. The owner often wants musicians to play at least a rounded 1-hour set, and the longer the musicians play for, the longer audience members and punters will remain consuming on the premises. That is, the length of a performance can clearly be an economic issue. Musicians, however, often feel that performing for longer than one hour is artistically too long – at the end of such a set the musicians are tired, both physically and creatively, and most audiences too become tired of listening.

MFM reiterated several times that an ideal length for a live set would be not more than 50 minutes. Neither performances extended for longer than 1 hour, nor those with an encore inappropriately tacked-onto the end, constitute what he believes to represent satisfying, 'rounded' performances. One exception to this convention according to MFM comes from one of the most celebrated jazz musicians to date: John Coltrane (1926-1967). Coltrane was a musician who could 'pull off' a performance lasting over an hour, "because he's just so creative". Creativity appears to be an additional factor determining the length of an improvisation, which can be related to the comment that an audience can only "handle so much information", if information here refers to the amount of creative output.

In addition to the overall length of a successful temporal performance, MFM emphasised the crucial importance of a musical set's *shape*:

> *"The most important thing you need to do to make the music work is make its shape: you need to build it up, up, get to where you're going, then bring it down again. That's all you really need"* (Interviewed on May 24th, 2008).

With respect to solo performance, MFM mentions that every effective solo needs to follow this structural shape: build up some excitement, take the music 'somewhere', then to lower the level of excitement at the end. A notable exception is Miles Davis, who according to MFM, plays much shorter solos and stops his improvisations at their 'peak', then his fellow musicians develop their solos from where Davis leaves off. Davis is said to be one of the only musicians who can 'get away with' this structure, but most others strive to shape their expressive performances with what Imberty (2005) refers to as dynamic curves of tension and resolution.

In every musical performance there are both highs and lows of what many listeners experience as 'intensity'. The experience of intensity can refer to both quantitative and qualitative characteristics of a musical performance (Hodson, 2007). Quantitatively, increasing intensity is related to increasing levels of various musical aspects including dynamics, tempo, rhythmic and harmonic density; each known as a technical means for "creating a continual 'ascension' to higher and higher levels of expressive intensity" (Hodson, 2007, p. 176). This notion has also been referred to by Jan LaRue as *growth* (1970), and Monson as *intensification* (1996), and is said to be the "most important criteria in defending the aesthetic and artistic merits of particular musical works" (Monson, 1996, p. 139). LaRue's concept of growth incorporates two ideas: movement – the motion created through micro-level musical activity, and shape – the large-scale form that results from this musical activity. Linking the two he poetically suggests that "Musical shape is the memory of movement" (LaRue, 1970, p. 115).

If shape and *good time* are each necessary elements of successful, expressive musical performance, then the two may be related: an experience of good timing may be partly a result of the shape of the intensification curves. In addition, in the investigation of musical play, Monson (1996) suggests that researchers should not be contented with identifying structural shapes alone, they should also be concerned with the interactive processes by which they emerge. Moran (2007) too has stressed the way in which the meaning of music can be an emergent property of interpersonal interaction. One of the main aims of this chapter is therefore to describe the musicians' process of intensification – to explore where instances or sections of good timing occur and to investigate whether the two are indeed related.

2. Defining the Methodological Framework

This study is principally interested in the process of large-scale musical play – how musicians work together to create an experience of good time and musical excitement in performance. A focus was made on large-scale development or the architecture of live musical performance, in addition to the processes by which the structure emerges. Three specific research questions were formulated to guide this investigation:

1) How do the musicians structure or shape their 'free' performance? Is this structuring or shaping similar on the 3 days?

2) Are there identifiable moments or periods in which the musicians agree that they are playing 'good time', i.e. that they are communicating well through musical sound? How do these moments or periods emerge and disappear?

3) What is the relation between the narrative shaping of the piece as a whole and the moments/periods of good time between the musicians?

One methodological issue involves considering how to identify the structure and segmentation of extended periods of improvisation with the aim of linking this organisation to occurrences of good time. It was decided to delimit 'episodes' (Mukherjee, 2008) – sections of growth and decline in intensity – with intuitive 'transitions' present throughout the musicians' improvisations. There is no fixed description of a transition in musical improvisation. But some common criteria used to locate these moments are *ralentandi* (deceleration), *diminuendi* (decreased volume) and lowered pitch. Lerdahl and Jackendoff's renowned generative theory of tonal music (1983), based on Gestalt grouping strategies, comprises a set of rules for grouping in musical audition and has been extensively employed in classical music settings, to greater and lesser effect. Importantly, these studies have shown that grouping tasks are relatively accessible for both musicians and non-musicians when applied to composed, Western classical music (Deliège, 1987; Imberty, 2005). However, acoustic criteria for the delimitation of episodes in improvised performance need to be defined. For ease of exposition, I will define a transition in musical improvisations as *a pause or moment of rest between episodes of intensification.*

A second methodological issue involves describing the occurrences of good time in the jazz musicians' freely improvised performances. The musicians themselves are considered to be best suited to describe these moments by reflecting on their experiences of the good timing between them. Defining good time in musical interaction has been an elusive task (see Chapter 3), but experienced jazz musicians can be remarkably self-reflective of their performance practices, partly because there is no external goal other than the process of their performance (Sawyer, 2003), and partly because a deep appreciation for improvisation's structures and secrets comes essentially from practice (Bailey, 1992). The musicians' verbal reports from Berliner's (1994) and Monson's (1996) ethnographic descriptions of jazz performance practices suggest that a musician's involvement in good timing is second nature – musicians often spontaneously comment on this aspect of both their own and others' performances.

3 An Exploration of Timing in Freely Improvised Jazz Performances

3.1 Setting up the study

Two professional jazz musicians, guitarist Misja Fitzgerald Michel (MFM) and drummer Christophe Lavergne (CL), agreed to participate in this naturalistic study. Both players graduated from French music conservatories and studied in postgraduate master classes in various parts of the world, and at the time of the interviews they were involved with teaching music themselves at a professional level and also had current performance engagements locally in Paris and nationally. MFM and CL belong to a network of professional jazz players in the Paris region, with mutual acquaintances in this network and have played together on several occasions. The players described themselves as being 'good friends' in a musical context, but they did not see each other regularly in a social setting. The last time they had seen each other was more than a year prior to the recordings made for this study.

The two musicians were asked to perform together in a rehearsal studio that was rented for the study, on 3 consecutive days for as long as they wished. They were asked to play freely without prior discussion as to what they would play but they were also asked to perform one standard of their choosing once on each of the 3 consecutive days. The musicians agreed on the first day that that standard would be "You and the Night and the Music" (Dietz & Schwartz, 1934). However, only the free improvisations were used in the present study. Two fixed cameras filmed the musicians continuously, from the moment MFM picked up his guitar to begin tuning it or from the moment Lavergne sat at his stool to begin tightening the drums' keys – whichever was first. The cameras were stopped only when the musicians started leaving the studio so as to capture not only their musical interaction but all other forms of verbal and non verbal exchange between them.

The recordings were made with minimal interference in the natural course of their musical interactions. It must be noted however that the presence of the cameras necessarily modified the situation from one of unconstrained musical exploration between 2 musicians to one where the musicians perform *for an audience*, the audience being a strange breed of researcher-listeners. The musicians expressed that they tried to make the performances 'listenable', but not 'forced', knowing that only themselves, myself and a handful of psychologists might ever hear them.

An additional particularity of these recordings was that they involved a drummer and a guitarist improvising together – a relatively unusual instrumental combination. Typically, either a drum-kit and bass or double bass would play together with the addition of one or more melodic instruments, or two or more melodic instruments would jam together. The guitar itself is also a comparatively rare instrument in jazz, with a wide range of expressive possibilities involving harmonic, rhythmic and melodic variation. In exploring their improvisations it was important to be aware of such particularities, as all duet performances are highly interactive – continual dialogue between musicians is crucial (Gratier, 2008).

In order to explore the basic felt structure of the musicians' improvisations, the first stage of the analysis involved describing specific aspects of the musicians' sound production. Acoustic traces of their performances were analysed by eye and ear to establish salient 'transitions' between episodes, and these transitions were graphed in time. The transitions have been selected by inspecting the videos (played back with audio) over several days and deciding where there were transitions between sections of musical play – transitions between two sections of increasing and decreasing intensity or growth. Two coders performed this analysis separately.

A second element explored in this study was the pulsed or non-pulsed nature of musical performance. We wanted to explore, over the course of each musical improvisation, how the musicians used timing at the pulse level, and whether this would contribute to a sense of good timing between them. Sections were delimited where one or both musicians were performing with a pulse or regularly repeating rhythm (pulsed sections), from sections in which neither of the musicians was performing with a particular beat (non-pulsed sections). In order to make this decision about the pulsed nature of their interaction it was necessary to listen through a recording until a change had appeared, then go back in time until the approximate point was located.

3.2 Interviewing the musicians

On several occasions I met with the musicians and talked to them both specifically about the recordings we had made together and about general performance practices. Two meetings were more structured than others: approximately one month after the recordings I met with each of the musicians separately and conducted semi-formal interviews where specific questions were asked about their impressions of the recordings made in March of that year. These interviews involved watching and listening to several excerpts from their filmed performances together, stopping the playback wherever the musicians wanted to and talking about these selected moments. The interviews were recorded, then transcribed, with precise times at which each comment was made with respect to the video recordings we were listening to and watching together. The interviews were conducted in French which means that the tables below contain my own translation of the musicians' words, often with some completion necessary to make the comments readable. The purpose of these interviews was to gain an impression of musicians' explicit knowledge about their performance practices when freely improvising together. This style of conducting interviews, meeting and speaking with the musicians in person and listening to musical examples together, is typical of an ethnographic approach to musical analysis.

For the second more structured interview, only the guitarist MFM was available to comment in an in-depth fashion on the recordings they had made. During this second meeting, MFM was asked to listen and watch again, and discuss the recordings with a specific notion in mind – the emergence of good timing between himself and the other musician. At this stage there was a lengthy discussion about what was meant by 'good timing'. In order to focus MFM's reflections, I shared the following anecdotal description with him:

> *Good time is not analogous to groove, as groove can appear in a solo performance, although the two terms are used interchangeably and are intimately related. Instead, playing with good time is that quality of music which emerges when two or more musicians are successfully collaborating together, coordinated in time.*

MFM was invited to comment on any element of the musical interactions that he felt related to good timing. In order to gain insight into the emergence or development of this experience, each of the three days of improvisations were systematically described by MFM, taking time to listen, watch and pause the music during playback whenever he wanted to explain a concept in further detail. During this exercise, he was also asked to either confirm or disagree with the temporal placement of the transitions that had been located.

4 Qualitative analyses of the musical improvisations

The following observations are exploratory in nature. The transitions we have located between episodes are in large part intuitive, based on salient features of most freely improvised performance, and their musicological nature has not been systematized in any fashion. MFM was free to comment on any aspect of the musical exchanges he felt was relevant to good timing, both musical and interpersonal, and no attempt was made to eliminate any 'unnecessary' comments. In addition, a descriptive analysis of the emergent musical material was performed, in order to further investigate the process of *intensification* of musical ideas in performance. Both musical events, MFM's comments, along with a description of some interpersonal events observed, were collated into one table and divided into episodes or 'songs'. Along the way, an attempt was made to link these episodes and their descriptions with the emergence of both good timing and creative output – an exploratory analysis of playing good time and musical meaning-making or *saying something* in improvised jazz performance.

The musical interactions between the two musicians settled into a routine that was identical over the 3 days of the study. This consisted in a period of free improvisation that began after about 15 minutes of settling into the studio and setting up the instruments, followed by a break of about 20 minutes after which the musicians performed the standard. Each of the musicians expressed that with regards to the improvisatory session it was common practice to play for between 45 minutes and 1.5 hours, and indeed the lengths of each of the three days of improvisatory passages were similar (days 1-3: 42 minutes; 43 minutes; 49 minutes; see Fig. 3 below).

During their improvisations, the musicians moved in and out of fragments or whole parts of songs and standards that they both knew. The commerce and negotiation of these lines, licks, and motifs is of great complexity and often these fragments are introduced rhythmically or harmonically by one or the other musician and immediately picked up melodically by the other.

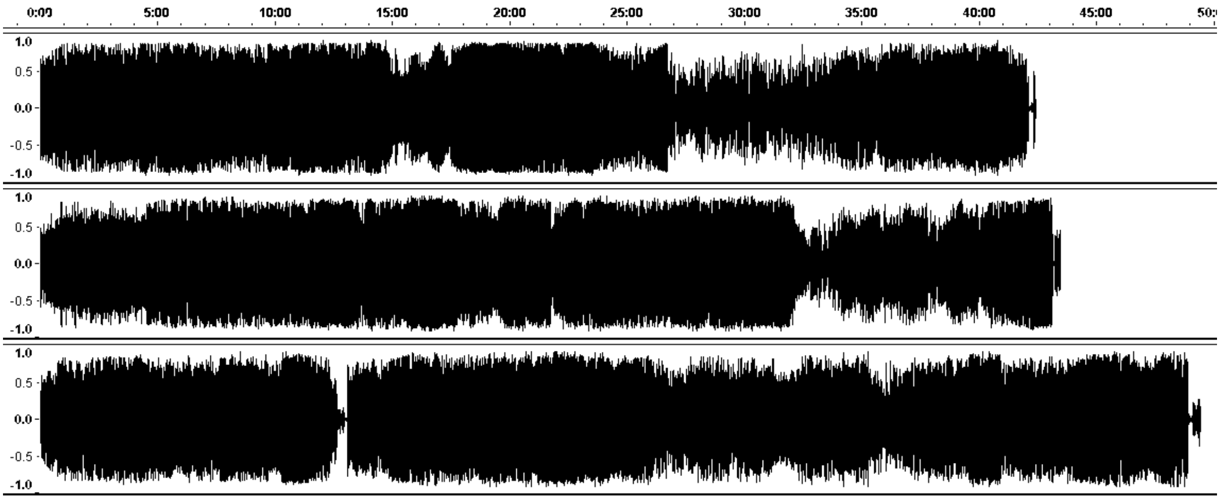


Figure 3: Three sonograms of the combined performances of Misja Fitzgerald Michel and Christophe Lavergne, displaying each day's improvisations in the studio (top-bottom = Day 1-3).

4.1 Narrative episodes

Both coders and MFM were in agreement about where transitions between sections of musical play occurred, which served to delimit extended narrative episodes or sections of increasing and decreasing intensity or growth. Each episode contained cycles of lower and higher periods of intensity. These periodic changes were fairly stable in time on days 1 and 2 – the lengths of the episodes were similar – even though their intensity could peak to a greater or lesser degree in each episode. On Day 1, the episodes lasted between 6min30sec and 9min40sec; on Day 2 they lasted between 8min10sec and 13min45sec (Fig. 4). On Day 3 the first two episodes lasted around 13 minutes while each subsequent episode became shorter and shorter – the last was 3min20. The average duration of an episode was 8.92 minutes [sd=2.92]. The musical and interpersonal event descriptions for each episode – 5 episodes on Day 1, 4 on Day 2 and 7 on Day 3 – are shown below.

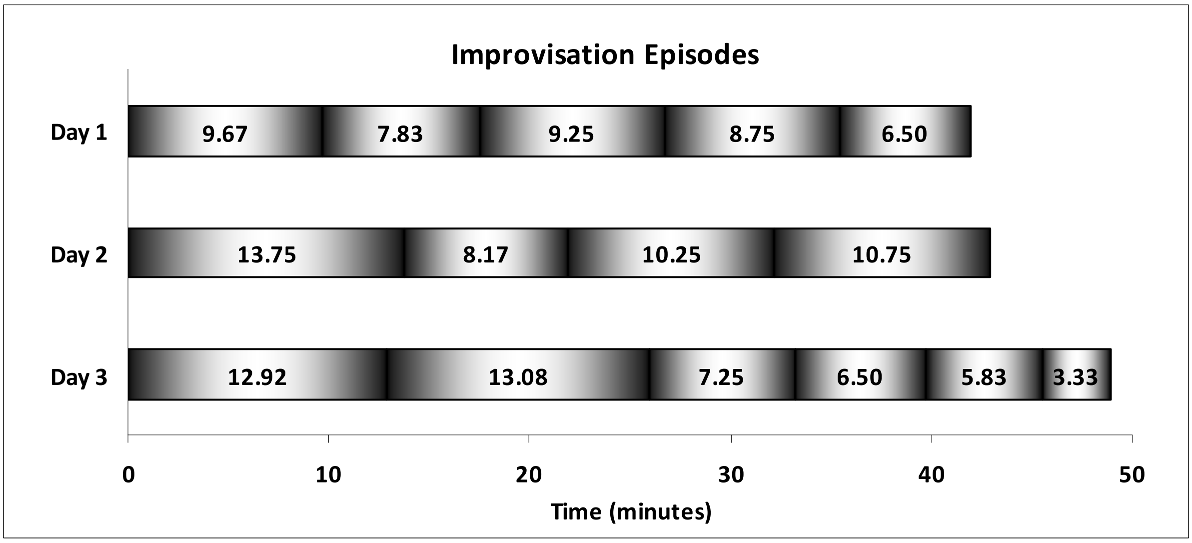


Figure 4: Lengths of narrative episodes measured between consecutive transitions, performed over 3 days of improvisations.

4.2 Pulse in musical improvisation

Additionally, both coders and MFM were in agreement about where to delimit sections of music with pulse and sections without pulse (pulsed/black and non-pulsed/grey sections in the figure below). Some pulsed sections were only transitory – lasting around 1 minute – and others were extended periods of pulsed musical interaction – the longest was on day three lasting almost 23 minutes. On Day 1 there were several changes from pulsed to non-pulsed material, but on Day 2 each of the sections was extended for longer periods. Almost the first half of Day 3's improvisations contained pulsed material, then there were regular changes from pulse to non-pulse again (see Figure 5 below).

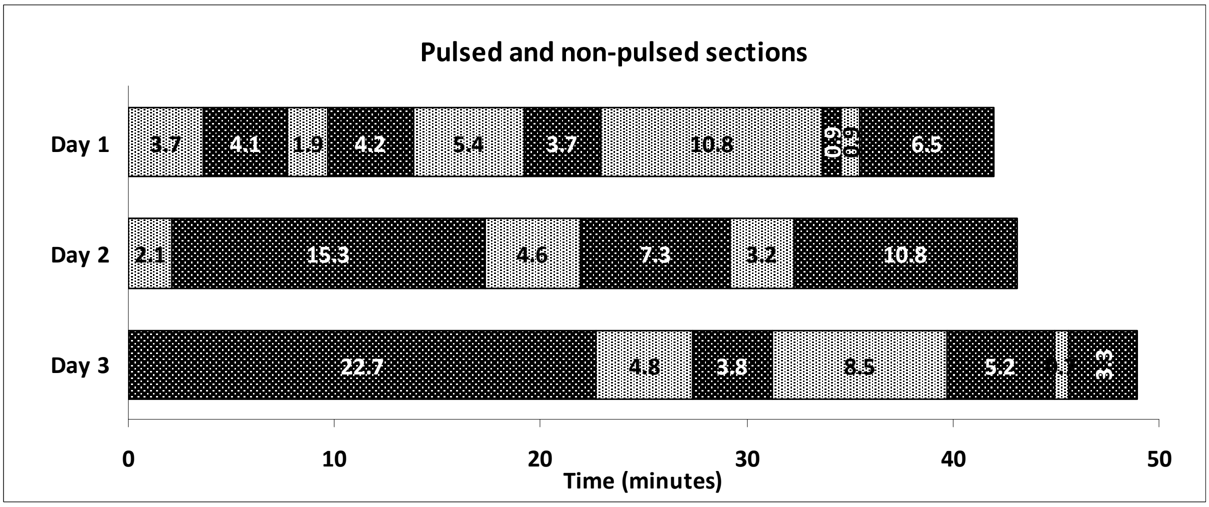


Figure 5: Pulsed (black) and non-pulsed (grey) sections located across each of three days of MFM and CL's improvisations.

The second stage of the analysis involved the musicians' recollections of their experiences of the process of playing good time. Based on MFM's commentary, each narrative episode's interactional content and its development was described, focusing on 'who' was involved in each musical event (the interpersonal events) and 'when' they occurred as the music unfolded in time.

5 Song Descriptions

Day 1 (Songs 1-5):

Song 1

Non-pulsed	1:50	MFM introduces melodic ideas in the key of E – putting the sounds into place MFM explores melodic and harmonic ideas CL uses mallets to create drum rolls, mostly on the cymbals CL plays around MFM, filling in his ideas with colour → CL is straight away in the same mind-set Both MFM & CL perform the morning's raga, setting the mood
	3:40	CL continues to colour MFM's playing with cymbals, reinforcing MFM's accents MFM explores melodic ideas using higher and more distant pitches from harmonic key
	4:10	CL's drum rolls become more soloistic MFM dampens his exploration → both musicians are following the rules of the game, No need to talk, they know what to do
	4:55	MFM sustains rhythmic arpeggios, building upon harmonic variations CL performs changes drum rolls – using toms, then cymbals – more frequently
	5:05	CL sustains a drum roll on both cymbals at once MFM expands upon melodic material at both high and low pitches alternatively – performing the role of bassist and soloist at once
Pulsed	5:30	CL changes to sticks and marks out time MFM adopts the rhythm and plays using quarter notes CL looks at MFM for the first time, 4 bars after introducing the rhythmic pulse → A groove is established
	6:10	MFM's performance becomes more soloistic CL keeps his role as accompaniment Cycles of 4 bars – "straight 8s" CL articulates these cycles by punctuating MFM's notes at the end of each cycle → their music is still fragile something is being installed over time
	7:10	MFM transforms material using chromatic tones, expands on melodic ideas CL reinforces rhythm at the end of every cycle with extended fills → Vague and not perfectly together in time Not good timing – but they manage to catch up
	8:00	Both players increase volume, increase excitement CL reacts extensively to MFM's ideas, follows straight away, bouncing back MFM makes rhythmic suggestions using strummed chords Shared rhythmic motifs A constant dialogue of questions and answers, simultaneously offered → **Really together in time**
	8:30	CL begins faster rhythmic tapping-out time on the ride cymbal Each taking turns at soloistic performance

		Constant negotiation of ideas
	8:50	CL looks at MFM again briefly
	9:05	CL solos as MFM provides harmonic and rhythmic background with chords MFM leaves space for CL's contribution CL solos with increasing intensity, cymbals, fast and rhythmic
Non-pulsed	9:35	CL's solo becomes more scattered, exploratory MFM **breaks the tempo down**, playing with rubato, returns to the first raga's pedal CL understands straight away, continues to play with speed but with irregular rhythms, reducing intensity
	10:00	Things are calming down CL provides colours and counter-rhythms MFM performs slow and soft harmonic chords and colours → Time dies away
	10:20	CL looks at MFM MFM performs a few subtle melodic lines CL decreases volume, keeping fast rhythms and turning them into shimmers of colour
	11:10	CL changes to brushes, fast rolls on different drums, exploring sounds MFM keeps constant pedal note, exploring high soft material over the top Both players reduce volume and intensity, increasingly sparse notes

<u>Song 2</u>

Pulsed	11:30	MFM's playing is broken and 'cut-up'
	11:45	CL comes in with sporadic fast, rhythmic phrases, punctuating MFM continues broken, rambling phrases Each player is simultaneously improvising on their own → Broken time, individual phrasing
	12:00	CL punctuates a little more often MFM's lines start to have a rhythmic pulse Permanent dialogue – each takes turns with soloing → Good dynamic of temporal space, nervous phrasing
	12:15	MFM plays a few lines as if he were the bassist Feeding off of each other's rhythmic ideas
	12:35	CL starts playing a few lines of fast, rhythmic pulse, then stops MFM plays a staccato, jerky motif; CL copies the motif rhythmically CL laughs Increasing pace and intensity
	13:10	CL could have started up a rhythmic pulse – the time feel is there – but chooses to play broken rhythms, feeding off MFM's rhythmic ideas MFM plays 'cut-up', fast and disconnected rhythms CL starts to get vocal, looking often quickly at MFM MFM is still the leader, but they meet each other along a common path Constant call and response in both directions A tempo is strongly implied

	14:00	They both laugh MFM chooses to leave space allowing a real exchange → **Good time**
	14:20	CL takes the traditional role of providing a strong tempo Both play with fast rhythms without form, a completely open section Each player responds to the other Cycles of 4 bars
Non-pulsed	15:50	Counter-rhythms, broken time, ‘cut-up’ CL cuts up time, using polyrhythm → **Time is still felt but it is broken**
	16:10	Moving into something different MFM plays less and less Solo drum section, cymbals Lots of smiles, CL explores rhythmic sounds with humour, loses a stick
	16:30	MFM stops playing after a sustained chord CL continues to play with excitement, fast nervous rhythms all over the drum kit Finds his lost stick as he sustains play with his other hand MFM laughs
	17:50	CL pauses for 2s – looks at MFM who is watching back – then keeps going with a big smile CL explores the sounds of his drum kit, jumping up, using his body
	19:20	CL moves to the toms, something else, which MFM understands MFM waits for the right space to come in

<u>Song 3</u>

Non-pulsed	19:25	MFM comes in with something new, trying to install something Bluesy feel CL continues repetitive sporadic tomtom pattern CL is waiting, watching – eyes on MFM between 19:30 and 23:30
Pulsed	21:05	CL introduces a pulse, still using the toms CL’s eyes continually on MFM’s playing
	21:30	CL plays the tempo CL fills in the space, punctuating, only with toms and snare drum The stable rhythm is still there, but they are breaking it, using variations → They are both playing with time, trying to break the rhythm
	22:30	Mixture of long and short phrases CL laughs, watching MFM’s playing CL remains with toms and snare drum but increasing intensity
	22:40	MFM becomes more rhythmic CL displays soloistic performance, exploratory, uses a little cymbals and hihat
	23:10	→ CL is keeping regular time
	23:50	A real dialogue, superposition of rhythms

		Mimicking rhythmic ideas CL laughs
	24:05	→ **Together in time**
Non-pulsed	24:45	Everything breaks up The music is hyperactive, fluctuating in every direction → **Time is being distorted** – stretched
	25:20	Both have understood that it's now something else, something rocky, funky Brief passage of rocky rhythm and guitar chords in unison: both laugh MFM plays short motifs, CL performance is soloistic → The tempo is there, but at the same time it is not
	26:00	Something surprising, free funk/blues Physically interesting to watch, lots of body movement MFM typically doesn't move much, but there's something there CL plays sporadic hits on different drums
	26:30	Mutual 3 second pause
	27:00	Moved to something else, fragmented structures and harmonies Big spaces between each line Sounds, noises and abstract phrases
	27:30	CL shifts to brushes MFM plays soft, lightly-fingered fast lines and some harmonics
	28:35	MFM comments 'a cymbal hit *Bang* and we've shifted to something else' whereas CL continues with quiet shuffling while MFM plays one sudden, sustained chord.

<u>Song 4</u>

Non-pulsed	28:35	MFM solos, says he doesn't know what he's doing CL waits, immobile
	29:40	CL rests, hands down, looks around
	30:15	MFM introduces the ballad "Another World" (*Written by Misja Fitzgerald Michel*) AABA form, each with 8 bars CL knows what to do as they've played this together before CL leaves space, supporting MFM with colour CL could have played a traditional ballad accompaniment but he chooses to open up space → No fixed tempo
	31:05	CL changes to mallets, slow rolls on cymbals → Continued fluidity and vagueness, no precise tempo
	32:10	CL returns to brushes after 10 second silence MFM continues to explore melodic variation around the song's form
	33:35	MFM signals to CL with his head twice, saying go on – express yourself CL solos a little, hesitating, continues to glance up at MFM often → Rhythmic trajectory is followed but it is not necessarily strict
	35:00	Both perform around the set of chords MFM has set-up Soft dynamics, long phrases

Pulsed	35:30	An example of a meeting point that never quite happened → CL suggests a pulse but MFM has not understood straight away
	35:50	MFM returns to the head
Non-pulsed	36:25	→ The pulse stops
	37:10	MFM has not accepted CL's proposition Difficult to play in this way MFM continues the coda

<u>Song 5</u>

Pulsed	37:20	They follow with something different straight away Create something using the last chord of the coda Playing 'straight 8s' – MFM repeats a cyclical motif CL plays with sounds and colours on the cymbals, repeating rhythmically CL manages to anticipate all of MFM's accents The sound is more 'pop'
	37:55	→ Complexification of the rhythm MFM plays double time – the 6-chord progression is being played over 12 bars MFM plays with a strong pulse, soft dynamics CL is in control and creates the mood CL looks up at MFM, then starts introducing stick hits
	38:50	CL intensifies – sticks on cymbals, louder volume. MFM strays increasingly from harmonic base
	40:30	CL solos, and laughs, and according to MFM, CL is saying "it's pop, listen we're playing pop music!" CL marks out the ends of each cycle with big hits, a firmly structured sound MFM is hesitant, vague, looking for a way to get out → Rhythmic music, but it hasn't worked out
	42:15	MFM attempts to break it up, trying to find an exit MFM tries different rhythmic motifs, returning each time to harmonic structure
	42:32	Both know that it's the end, both are calming down Decrease in intensity, slowing down, classic and open MFM returns to a melodic display of ideas
	43:50	CL moves to rolls, MFM slows down A 'normal' ending Long pause after the last note, MFM says "I thought it was never going to end!".

DAY 2 (Songs 6-9):

<u>Song 6</u>

Non-pulsed	00:35	CL explores sounds with his bag of percussion MFM Starting out with harmonic cycles of arpeggiated chords Blues feeling in E, played with rubato → Internal tempo with variation, that they could follow Could be counted out but not quite in tempo
Pulsed	2:35	MFM plays short passage of rhythmic pulse CL continues exploration with percussion
	3:00	MFM returns to rubato section MFM creates harmonic tension, keeping the basic structure CL changes to mallets
	3:15	MFM reiterates felt pulse, becomes internalized C continues long rolls with mallets on cymbals A little long but it doesn't matter MFM plays arpeggios, folky feel → stretching time
	5:05	MFM lances the tempo – a swing song CL knows and recognises straight away – this is known material
	5:35	CL enters with swing feel using sticks, as MFM plays the basic harmonic structure
	6:00	MFM starts a solo over "Chase" (*Written by Misja Fitzgerald Michel*) 12-bar harmonic cycle After MFM's first 12 bars he stops, indicating to CL to 'trade' 12 bars each MFM & CL both follow the form The ideas of each are feeding the other
	7:15	Rhythmic mirroring Big smiles on both musicians → **Playing good time**
	7:25	Better now, difficult at the beginning Questions and answers, rhythmic punctuation
	8:30	MFM anticipates the end of CL's rhythmic cycle CL has understood and follows Each are feeding the other
	9:10	The 12-bar cycle has finished, the groove continues Rhythmic exchanges
	9:55	CL laughs because MFM plays some 'Coltrane changes' Punctuation, dialogue, heating up for two minutes now → More together now, they've woken up
	11:00	MFM starts a pedal point amongst fast rhythmic lines Then MFM plays traditional soloistic lines Joining rhythmically at ends of phrases in unison
	12:00	CL plays solo, MFM keeps the form with chords MFM plays some reference points for CL but he doesn't need them

	12:30	CL carries on soloing → Good time together
	13:15	MFM performs the role of bassist Constant dialogue, counter-rhythms in every direction CL continues soloing in theory but they are both sharing ideas → Really good time together
	14:00	Both play loud, broken, jerky rhythms Sharing some rhythmic ideas in unison It's the end, something else

<u>Song 7</u>

Pulsed	14:20	Double time – the form is still there but not the same groove CL plays regular hits on different drums, accenting the ends of phrases
	15:00	MFM improvises in E, folky and reflective Rhythmic interaction, lots of movement → They're tired, but more together than yesterday
	16:00	Both explore broken variations, punchy and accented CL glances up at MFM
	17:00	Funky feel, straight 8s CL leaves space to fill in Often mutual 1 second pauses
Non-pulsed	17:55	Broken, like [day 1]'s ideas, de-structured, nervous and fast Individual expression, each exploring
	19:00	CL starts playing ultra rapid rhythmic lines MFM follows with rapid melodic ideas → Time is there now inside them, but they don't need to play it
	20:30	CL smiles – more interaction CL using percussion and fragments of rapid dance rhythms Questions and Answers rebounding one after the other
	21:00	Taking turns playing rapid phrases CL often looking over to MFM
	21:30	Phrases are getting tangled up but are changing dependent on the other person CL vocalizing, laughs several times Longer extended melodic and rhythmic frenzies → Interesting moment, good ideas
	22:20	CL introduces slow repetitive hit, then MFM joins in They both accelerate linearly over 4 seconds MFM starts run of chords, CL tries to follow rhythm, misses one beat then vocalises

<u>Song 8</u>

Pulsed	22:30	MFM introduces a song in 7/4, CL hears it and recognises it straight away AB theme, "Swinging Heart" (*Written by Misja Fitzgerald Michel*)

	23:00	MFM repeats rhythmic motif over and over, waiting for CL to fully join in CL getting slowly into the groove, playing with increasing intensity MFM laughs as CL's intensity increase is not slowing down
	23:30	MFM solo Not easy to keep 7/4 time when you're only two musicians Rhythmic shifts, superposition of other rhythms → Keeping the internal tempo **They're together in time**, but it's not easy to do
	24:00	CL plays traditional role of keeping stable time MFM soloing extensively around, exploring melodic ideas with song's form
	27:45	CL looks up at MFM several times
	28:00	CL plays drum kit solo MFM supports taking the bassist's role
	28:50	**CL plays alone**, organic expression MFM continues to move rhythmically without playing CL exploring sounds of the kit → MFM feeling the groove, no need to count – if you lose the feel You just wait until the other gives you a sign of where they are
Non-pulsed	29:45	CL becomes more free in his interpretation of the rhythms De-structuring time, complicated counter-rhythms MFM looks around at camera
	30:30	CL plays fast, sporadic rolls and rhythms, with slowly decreasing intensity and pace MFM becomes still, watching → The pulse is lost
	32:30	CL plays slow, repetitive hits on ride cymbal and snare drum only CL stops, MFM follows after 1 second of silence

<u>Song 9</u>

Pulsed	32:55	Something new, CL ends his solo, de-structures – CL is exhausted! MFM introduces slow chord progression MFM plays 4 bars taking the role of the bassist → Slow, steady tempo
	33:55	MFM plays Waltz Macabre in 3/4 (*Written by Bill Carrothers*) New song with structure and precise melody → Measured out, in the rhythm
	34:00	CL plays time with a brush and his hands, then mallets CL explores sounds which go perfectly – soft screeching, some percussion MFM and CL smile at each other briefly after screech
	36:05	CL free from marking out time, more exploratory, soft eerie colours CL acting the clown, mallets in the air in between strokes
	37:05	MFM explores eerie melodic lines, soft intensity, bending strings, at the same time maintaining harmonic progression CL explores with percussion sounds

	39:05	MFM returns to the head CL comes back in with structured time using brushes and mallets
	40:30	Repeating the last chord of the cycle, MFM leaves space for CL to colour things The outro allows CL to explore, drum solo ad-libbing
	42:20	CL looks at MFM twice, who’s not looking Later, MFM looks at CL several times who’s also not looking
	43:40	Mutual eye contact → The last bar is played rhythmically in unison

DAY 3 (Songs 10-15):

<u>Song 10</u>

	9:45	**CL takes his playing down a notch**, quieter dynamics, fewer counter-rhythms
	0:05	MFM plays a rhythmic, pulsed cycle of harmonies, waiting for CL to join in! MFM repeats what might be called the head
	10:20	Cycle of harmonic material created on the spot MFM starts a new rhythmic motif – the same song, but another section of it
	2:00	CL enters, plays with drum kit sounds, taking his time, not stating the pulse clearly Spontaneous composition MFM solos but retaining rhythmic and harmonic pulsative path CL supports new idea with a rocky feel, using tambourine → Rhythmic relay with phrases created around it CL finds a particular groove corresponding to the mood each time
	4:20	CL looks at MFM Little by little things fall into place → Something different but essentially the same tempo and groove MFM exploring more freely, using fuller range of pitches
	11:30	MFM returns to the beginning, distorting some chords CL reserved rhythmic activity on one or two drums rather than the ensemble, CL repetitive rhythms, reduced intensity changing mallets and looking down at his selection of them
	5:00	Decrescendo, moving into something else MFM not together with CL – MFM has made a mistake and now he’s lost Internal pulse is still there CL catches up, moving onto cymbal strokes, accenting on the snare Both quiet down to almost no sound, then long 5 second pause Not at all controlled; a harmonically-complicated song cycle
Pulsed		Needs both melody and harmony for this song to work
	6:30	Something was created in the beginning that didn’t work straight away CL performs more traditionally, still looking around for other mallets MFM develops on melodic lines → Tight, ‘straight 8’ feel
		MFM plays repetitive motif from the beginning, with rhythmic variation CL plays on ride and snare, looking into the distance
	7:45	MFM reduces his play to indicate that CL should play a drum kit solo CL understands straight away Mutual smile after 15 seconds of solo **→ They’re both playing well in time**
	8:00	CL is being adventurous, continual counter-rhythms MFM supports CL with stable repetitive motif
	8:30	CL leads their development, takes control Trust for each other and experience allow them to catch up again Mutual smiles and laughs, CL vocalises → Really good time, finally caught up They’ve both internalised the rhythm, smiles continue

Song 11

Pulsed	13:00	MFM introduces the song "Inner Urge" (*Written by Joe Henderson*) Normally it would be played in 4/4 but MFM introduces it's rhythm in 7/4 CL realizes the implications straight away and takes off his jumper – it's going to be fast! MFM laughs, thinking good idea!
	14:00	CL enters with cymbal rolls using mallets, accentuating some notes → Each has internalised the time – they're together at each beginning and ending of a phrase
	14:50	CL starts regular rhythmic groove, but using mallets on the snare MFM varies harmonic material
	15:30	MFM cycles through the theme, always varying Constant dialogue with the song's form, harmonic and rhythmic super-positions → A classic groove starts up
	15:50	MFM plays guitar solo CL supports with rhythmic pulse, still exploring toms and snare
	17:15	CL brings in cymbals, fast straight feel Questions and answers from both musicians
	17:45	MFM bends his knees playing an elaborate melodic line CL vocalises just afterwards → **Together in time**
	18:00	Anticipating and punctuating each others' ideas CL is playing the role of making the groove; supporting MFM's ideas and conversing with him at the same time Play highly similar rhythmic lines in unison – CL laughs and looks at MFM → Briefly not together, MFM makes a mistake, not a serious one
	19:00	Rhythmic notes played and accented in unison Constant dialogue of ideas → Really together in time
	19:50	CL vocalises, intense, fast rhythms and counter-rhythms
	20:35	CL plays drum kit solo MFM plays the role of bassist to provide harmonic structure CL is suffering! Trying to get something out.. → Really good time, CL looses a cymbal crashing on the floor
	21:50	The pulse become less pronounced, some sporadic pauses The 7/4 feel is still there, but in a de-structured way
Non-pulsed	22:50	Doubling time, thinking about it differently CL explores other sounds on the drum kit MFM plays with the harmonic feel, chromatic passages → Time is still there but entirely **de-structured**
	24:00	Still together in time, even if it is completely de-structured Punctuating each other's sparse phrases

	24:30	Mimicking each other's ideas MFM calls this a 'humourous' passage : because CL is a drummer that really listens CL vocalizes Anticipating each others' ends of phrases
	25:45	No longer in 7/4, an open rubato passage

Song 12

Non-pulsed	26:05	Another song, moving along to something else MFM introduces part of the song "Mirage" (*Written by Misja Fitzgerald Michel*) Normally it is played in 3/4, but MFM starts it going with a 4/4 feel CL has stopped playing
Pulsed	27:30	CL enters with a rhythmic pulse using percussive sounds, tambourine, shakers MFM makes facial grimaces, repeating slow harmonic cycle → Some rhythmic pulse
	28:00	As a duo it's difficult to play this piece, very harmonic song Not the best option to play only with 2 people, not enough support Some nice ideas, but too long and not particularly interesting to listen to Much freer and more experimental CL leaves extended gaps
Non-pulsed	31:25	MFM stops playing, nods to CL to take over CL plays an ad-lib drum kit solo MFM knows it'll be long because it's a slow groove, so he sits down CL explores sounds and rhythms

Song 13

Non-pulsed	34:40	MFM introduces some slow chords Pure improvisation here, exploration of sounds and colours MFM plays with the button on his guitar to mimic the effects of a volume pedal
	36:25	MFM's phrases are completely free and improvised CL creates phrases in his own way Each are constantly listening, exchanging phrases between them
	37:00	MFM plays more melodic lines, exploring full range of his guitar CL changing between different percussive sounds and mallets
	38:30	Ornette Coleman-style improvised melodic openings Faster rhythms but the same quiet intensity → Phrased arches, with no precise tempo
	39:00	CL looks over to MFM on a few occasions Each in different sound worlds

Song 14

Pulsed	39:50	A jerky, staccato, chopped-up groove, but the rhythm is there CL follows everything, at the same time he's reserved, holding back and listening intently → A tempo starts up little by little
	41:15	CL comes in super rhythmically – playing time but also punctuating every idea MFM playing fast melodic lines → Stronger rhythms established
	42:00	MFM returns to a motif already played CL hears it and knows what MFM is doing It's all on – they've found some common ground together CL laughs Super-position of rhythms Taking up some ideas but not others → **Swing section – great time**
	43:40	The groove changes – breaking it up a little so that the drum kit can have a solo CL plays drum kit solo CL watching MFM, while playing ultra fast swing
	44:10	Back into the groove Constant exchange, CL looks at MFM, vocalises → Rhythmically together
	44:55	Almost shifted into another tempo but didn't CL playing jokingly, staccato, bouncing in his seat MFM swaying rhythmically
Non-pulsed	45:00	Moving on to something new → **Time breaks up**, slowing down

Song 15

Pulsed	45:40	CL starts playing with 5/4 pulsative rhythm CL's playing spread out over the drum kit MFM playing minimal arpeggiated chords
	45:55	MFM returns to a previous harmonic chordal arrangement, joining in with CL's pulse, but not in 5/4
	46:20	CL plays rhythmically over the drum kit, alternating sounds MFM didn't quite understand where CL wanted to go, so stops playing Which means that CL stops accentuating it as a 5/5 feeling, and ends up playing continued rhythms

	46:30	MFM comes back in with slow chordal changes, playing with the volume controls, leaving long gaps between sustained chords MFM has now understood what CL was trying to install, but it's too late CL's playing is more and more sparse, still pulsative
	48:45	MFM stops first, leaving chord to sound out CL repeats rhythmic combination several times with fewer and fewer notes, then stops
	49:00	After they stop playing, MFM apologises verbally for not understanding at first Both MFM and CL then laugh together

5.1 Making sense of the musical descriptions

The current study focused on the moment-to-moment communicative interplay that can take different forms in musical play. Firstly, these three days are a reflection of the organic nature of making music in a jazz genre: the musicians were clearly performing together collaboratively, suggesting and sharing musical ideas as the performance unfolded in time. Secondly, MFM insisted that it was a difficult task to comment on and/or explain their musical improvisations, other than by an intuitive means and describing events using varied metaphors of colour, shape and feeling implied. For MFM, their collaborative success – being able to meet together along common pathways – was principally due to two things: common cultural knowledge of specific and non-specific jazz conventions, and a specific kind of *listening*. MFM stated that he felt responsible for imposing his music a little more than CL, especially at the beginning, but that, just as others have stated (Berliner, 1994; Monson, 1996; Gratier, 2008), a constant dialogue of ideas passed back and forth between the musicians was of crucial importance for their meaningful communication.

Furthermore, both musicians commented that it was not an easy task performing on three consecutive days: a great deal of creativity was called for as they were trying each morning to create something 'listenable' for their implied audiences through the camera's lens. Despite the difficulty, it was not an unpleasant task – rather, both musicians felt it was a real opportunity for creative exploration. As it is rare for two professional performers to have the time to improvise together so freely over three days, without any particular concert in mind, these recordings provided that opportunity.

As a consequence of performing together over three days, distinctly different musical expression emerged in each improvisation. On the first day their improvisations were, according to MFM, uptight, fast, nervous and too dense, partly due to the fact that they had to accommodate playing in front of a camera, and partly because the musicians were exploring and re-discovering their musical relationship with one another. In summary: a musical set that was fast, dense, and "trying to get something out". On Day 2, according to MFM, there was a feeling of musical complicity between them; both musicians certainly looked at each other more often than on days 1 and 3. According to MFM the ensemble was more relaxed, breathed more, was more fluid, and in addition, it was far more of a formal set than the other days, performed as if in a live concert situation. On Day 3, their improvisations were more creative and unknown, involving spontaneous yet fragile material, which often didn't work at the start of each song. A lot of the music, although not particularly 'impressive' according to MFM, involved trials and sketches of new musical ideas – according to him the best way to develop material to be used later on.

In addition, several important aspects of their performances emerged from the descriptions that are discussed below under the following headings: Roles, Creativity, Movement, Architecture.

5.2 Roles

Each musical player had a different role in the duet which clearly contributed to their musical interactions at different levels. It is important to note that there is generally a significant difference between improvising as two players and being three or more, a subject which both musicians reiterated several times. As a duet of drummer (CL) and guitarist (MFM), in terms of harmonic and melodic content MFM was much freer to explore melodic ideas, and less restrained to specific chords or progressions determined by other musicians. But in other ways MFM was bound to providing the harmonic basis even if he then took the role of soloist, limiting his soloistic performance comparatively. Importantly though, a two-musician ensemble provides an ideal stage for meaningful exchange – as two players they were forced to communicate at all times, being in a position of unavoidable conversation.

Generally, CL fulfilled a rhythm section role, sustaining the rhythmic time-feel, while MFM performed melodic solos over this. However, often MFM performed the role of rhythmic stability around which CL was able to be freer in his rhythmic expression. Both musicians regularly shifted between roles, sometimes taking the role of soloist and sometimes of accompaniment or rhythmic base; MFM in particular compensated for the lack of bassist who might have been performing had it been a standard jazz group configuration by regularly playing a few bars of walking bass with a lower pitch. In addition, there were some lengthy passages where neither musician was in a position of soloing on his own – both were soloing together as they bounced ideas off one another, backwards and forwards. Interestingly, MFM emphasised that, overall, each player had their own role to play, and in addition, *in the moment* they were 'equal' contributors to the musical performance. In Song 1 at 6:10, MFM mentioned that "[CL] is able to reply all the time, while maintaining his role of time-keeper". Further along at 8:00, he mentions "That's why [the music] works – because [CL] is always listening (*Il est dans l'écoute*). […] He'll suggest something, and at the same time he'll be punctuating [my ideas]". Both musicians were continually negotiating and matching their ideas at the level of rhythmic phrasing.

5.3 Creativity

MFM often made the distinction between musical material that he felt was created or *became a new event* – something that surprised him when listening retrospectively as being original material – compared to musical play that did not surprise him, or which referenced *a musical event gone before,* such as another musicians' signature riff or a melodic line from a standard they knew. During the course of their improvisations, five standard tunes were evoked, including three of MFM's own compositions, and two of other musicians' work (*Joe Hendersen* and *Bill Carothers).* MFM was always responsible for introducing these standards, by playing the harmonic chord progression associated with each song. CL knew very quickly each time and adapted his playing according to the mood of the song. For example in Song 9 at 34:00, CL recognised the song and improvised his sounds with respect to its title – making screeching noises on the cymbals to fit in with the "*Waltz Macabre*". Sometimes the tunes were played with the time-feel that is normally associated with them, but twice MFM introduced the songs with a different time-feel as a way of varying the material and making their improvisations their own. At the beginning of Song 12, MFM introduces part of the song "*Mirage*" which is normally played in 3/4, but MFM starts it going with a 4/4 feel. And again at the beginning of Song 13 MFM introduces the song "*Inner Urge*" in 7/4, whereas typically it would be played with a 4/4 time-feel.

One element discussed with both musicians in earlier interviews relates to an 'acceptable' amount of creativity. CL talked about the way in which an improvisation can never involve purely creative output – something completely new – even within contemporary 'free' improvisations. In a typical solo lasting around 4 minutes, a musician will play approximately 1 minute of completely new musical invention, and the rest will be a variation or combination of musical material gone before.

The length of passages of creative endeavour is clearly in the minds of performing musicians at all times. In CL and MFM's improvisations, at the beginning of every song there was new material created on the spot, aside from those passages where they performed known standard jazz tunes. Over the three days, as MFM intuitively noticed, there were more and more creative attempts – on Day 3, 6 songs or episodes emerged which were shorter and shorter as they quickly shifted onto new material. Sometimes their creativity developed into something useful or something they enjoyed playing for a continued time-span, yet sometimes they created something that they didn't particularly enjoy, such that they abandoned the idea very shortly after. For example on the first day in Song 5 at 30:40, a new sound was created with a feel that they didn't particularly enjoy – CL started to laugh and exaggerate his movements, indicating to MFM that he meant "it's pop, listen - we're playing pop music!" and MFM commented that he was looking for 'a way out'.

5.4 Movement

Physical reflections of the two musicians' collaborative interaction were also evident throughout their performances, although movement was not explored in any systematic manner. These included the use of opening and closing their eyes, watching each other's instruments, mutual eye contact, facial expressions, non-verbal vocalisations, and movements of the body including whole-body posture. For example, both musicians tended to orient themselves in a particular direction as if toward virtual categories of space, then changed their orientation several times over the course of their improvisations, which evokes Goodwin's (2002) concept of negotiated phases of engagement and disengagement. Interestingly, there were significant differences in the way each of the musicians tended to change their orientation and move in space – the manner in which they used gesture and posture as they improvised together. CL for example was particularly overt or manifest in his use of gesture, whereas MFM was by comparison reserved, moving with a minimum of gestures necessary for his performance.

The process of watching themselves perform visually in the video recordings was often revealing for the musicians. On several occasions, by observing a mutual laugh or smile or particular gestural feature, MFM gave an account of the interactional moment as a result. For example when he noticed that CL was vocalising at a particular moment, he suggested that it was because he was 'suffering' – involved in an especially physically-demanding section of their improvisation *because* of the number of creative ideas that were being exchanged at that time.

5.5 Architecture

Both musicians repeatedly referred to the 'architecture' of a successful performance. For MFM, architecture includes the acceptable length of an improvisation or solo section. As Berliner's (1994) description of one of the social conventions in jazz suggests, each soloing artist sets the stage for the next, such that if he plays for 5 minutes, the next musician should not play for more than that same length of time in order to give a 'respectful' performance (Duranti & Burrell, 2004). This musical convention generally refers to two melodic instrument solos, although similar principles apply to rhythm section members also. If both musicians decide to play for the same length of time, say 5 minutes, and if the musical group had 3 soloing musicians, then including the 'head' and the 'recap' a performance would last around 20 minutes, which MFM remarks as being too long for one song alone. Importantly, the length of a solo section will always influence the length of each song and thus the length of each live set.

There were several indications that each musician had in mind an image or idea of the architecture of their improvisations. For each song or episode in their improvisations, the length of the solo or soloistic passage was clearly playing a role in organising their improvisations: the players alternated between the role of soloist and the role of accompaniment, despite MFM making extended soloistic performance being the more melodic instrument of the two. In Song 1 for example, MFM described his performance as soloistic between 5:05 minutes and 8:00 minutes, then a period of intense dialogue followed, after which CL performed a solo from 9:05 minutes until 10:00 minutes while MFM provided a harmonic and rhythmic background with rhythmic chords, 'leaving space' for CL's contribution.

For both musicians, architecture also refers to the evolution or development of musical intensity, which LaRue terms *growth* (1970), and Monson terms *intensification* (1996). CL mentioned that within each song, "[he] was trying to get somewhere, build it up and create something intense together", and for MFM, a great player "knows how they're going to get to Point B when they're at Point A" (pointing his finger and drawing an arch). In their improvisations, MFM often commented on a passage's 'increasing' or 'decreasing' intensity, although these passages did not correspond consistently to any one criterion, such as *ralentandi* (slowed pace) or *diminuendi* (dampened volume). At the end of Song 1 for example, after CL's solo MFM comments that things are 'calming down' as both players reduce volume and intensity. MFM performs slow, soft harmonic chords and subtle melodic lines, as CL maintains rapid rhythms but turns them into dampened shimmers of colour, and time 'dies away'.

6 How did good time emerge over the course of their improvisations?

In saying that time 'dies away' when the intensity of a musical passage was reduced, MFM is providing a subtle link between the developmental shape of a song and good timing. In order to summarise the emergence of good time, the first appearance of 'good timing' or any similar description ('in time together', 'playing well in time') was located, as well as any term implying that good timing was finished ('time breaks up', 'de-structured time'). These 'start' and 'stop' times were converted into time with respect to the beginning of each song (Table 4 below).

	Song	'Good Timing'		Pulsed/non-pulsed
		From (mm:ss)	Until (mm:ss)	
Day 1	1	6:10	7:45	P
	2	2:30	4:20	P
	3	4:40	5:25	P
	4	*"Meeting point that never quite happened"*		
	5	*"Hasn't worked out"*		
Day 2	6	6:40	13:25	P
	7	*"Good ideas"*		
	8	1:00	6:20	P
	9	*"In the rhythm"*		
Day 3	10	7:40	9:40	P
	11	4:45	9:50	P
	12	*"Difficult to play this piece"*		
	13	*"Different sound worlds"*		
	14	2:10	5:10	P
	15	*"Too late"*		

Table 4: Occurrences of good timing as experienced by MFM during their freely-improvised performances.

Good timing did not occur systematically within every interactive episode, instead there were passages of good timing that emerged each day – three instances on Days 1 and 3 and two instances on Day 2. On three occasions (songs 6, 8 and 11) good timing was used to describe a significant duration (over 5 minutes) and the better part of the episode. For example on Day 2 in Song 6 MFM commented that they were *"playing good time"* at 6:40 and continued to mention the experience ("*more together now", "really good time together"*) until the end of the song. On 5 occasions (songs 1, 2, 3, 10 & 14), however, good timing lasted around 2-3 minutes. In each case it was described during a passage of increased intensity, often in the middle passages of each episode.

The first point to mention with respect to the context in which good timing emerged is that dialogue always went hand in hand with an experience of good timing. Indeed the most pervasive of MFM's comments, although he was invited to comment on the timing of their improvisations, made reference to a musical dialogue or exchange of musical ideas, but this was particularly the case near instances of felt good timing. In Song 1 for example, at 8:00 when MFM mentions that both musicians were *"really together in time",* he also mentioned that CL reacted 'extensively' to his ideas, followed 'straight away', 'bouncing back', and that there was a *"constant dialogue of questions and answers"*, simultaneously offered. Again in Song 11, when MFM mentions that they are *"together in time"* at 17:45, within a minute either side of this comment he also mentions *"questions and answers from both musicians"*, *"anticipating and punctuating each others' ideas"*, *"conversing"*, and a *"constant dialogue"*.

In addition, good timing always occurred within passages that were pulsed – in which one or both musicians was providing a regular, rhythmic pulse to their performance. This may have been a result of MFM's understanding of the term 'good timing', although at no point did we evoke the idea that the experience of good timing between musicians should only be described when there was an underlying, periodic pulse. Rather, MFM is intuitively associating the two, indicating that to some extent a stable rhythmic framework may be necessary for good timing to emerge. Furthermore, good timing often occurred in the last part of a pulsed section, and was disrupted when the music became non-pulsed (in songs 1, 2, 3, 8, 11 and 14), indicating that the process of *establishing* (and breaking down) the pulse might be related to an experience of good time. Clearly, an experience of good timing is intimately related to pulse-level events – both the periodicity of rhythms in the moment and their implied tempo or pace, including setting up that tempo together. Finally, passages in which MFM commented on their good timing occurred often near a moment when either CL or MFM smiled or laughed.

7 Discussion

These results have shed some light on the processes through which good timing emerges during a freely-improvised jazz duet performance. When both MFM and CL played together they intuitively organised their play on both larger and smaller scales of interaction.

7.1 Narrative episodes of collaborative work

At a larger scale, both musicians spontaneously created narrative episodes or 'songs' which lasted between 3.5 minutes and 13.5 minutes in length, of which the mean duration was roughly 9 minutes. This study can offer only a limited perspective on the preferred durations of collaborative, musical episodes that likely exist in a wider sample of performances, but it also points towards universal mechanisms of time cognition that may underlie the negotiated temporal organisation of music performance. Clearly, each musician had in their 'mind's ear' an image or idea of the architecture of their improvisations. Each narrative episode began, developed and ended in a motivated and emotionally-charged frame of time. At the outset of each song, either the introduction of a jazz standard was offered by MFM, or musical material was created and developed in the moment. Following this, always in accordance with implied or explicit jazz conventions of creativity and roles, each song contained a characteristic development of ideas, moving into passages of increased intensity, often accompanied by climactic, *good* timing, and a section of decreasing intensity as the players moved into the next song. Such a pattern of musical collaboration can be compared with the "cyclic flow of excitement" in recordings of mother-infant interaction (Mukherjee, 2008, p. 301), as the dynamic narrative cycle of interaction is common to both.

In addition, this study has explored the emergence of good timing with respect to meaningful narratives characteristic of each song, to a greater or lesser extent. As moments of good time were consistently noticed and commented on in the middle passages of several, although not every, song this implies that moments of good time were closely involved in the structure or organisation of their musical improvisations. Importantly, I wanted to further define the experience of good time in a highly communicative and improvised setting, by seeking any elements that might be sufficient for its emergence.

7.2 The emergence of an experience of good time

Two such elements came to the foreground. Firstly, passages of good timing emerged when there was concerted dialogue – when both musicians were simultaneously listening intently to the other's ideas and using these ideas to develop their own. Each musician 'fed' from the ideas of the other, as when for example in Song 1 MFM decided to 'break' the tempo down and return to an initial melodic idea, followed closely by CL who continued to play with speed but with irregular rhythms, reducing his rhythmic intensity. This is in fact a defining feature of musical improvisation in a jazz setting. In Chapter 3 (sections 3.3 and 3.6) the importance of listening attentively to a musical partner was evoked, not only in order for a musician to be able to temporally coordinate their movements precisely with others, but also in order to demonstrate their social involvement. This notion has been illustrated here through the qualitative descriptions of musicians' interactions in relation to the creation of an experience of good time. The musical intensity that develops over the course of an improvisation is clearly reliant upon ultimately social processes based on the ways in which two cultural individuals coordinate their activities sociably in time.

Furthermore, passages of good timing were always within sections that were pulsed, implicating a marked link between the periodic organisation of rhythm and an experience of good time. At an finer pulse-level still, several of CL's accented hits or brush strokes and MFM's emphasised plucks or strummed chords appeared to be minutely coordinated in time, and this coordination was perceptually different during passages when MFM experienced good timing, and passages in which their play 'didn't work'. As it was suggested in Chapter 3 (section xx), it may be that at this subtle micro-temporal level, an exploration of the way musicians coordinate and interlock their musical motives together may contribute further to understanding the experience of good timing between them. As the passages of good timing occurred in conjunction with attentive listening and dialogue, it may be that timing at the pulse level is also a result of the communication or dialogue between musical partners. In addition to individual expressive timing, there is a need to explore the role of temporal synchronisation or matching at the pulse level in collaborative music-making settings, which I set out to do in the following chapter.

Finally, quite understandably good timing often emerged close to moments when one or both musicians smiled or laughed – during an outward sign of appreciation for their collaborative endeavour. Naturally, the experience of good time evokes enjoyment – the process of making music together is *seriously* fun – echoing the ideas evoked previously that musicians' coordination is also a collaborative endeavour holding aesthetic value in itself.

Describing freely improvised jazz performances and the musical performers' experiences of them has provided some insight into the ways in which two musicians make music together with good timing. However, there is a need to complement these analyses with finer measures of the temporal aspects of their individual and joint productions – for example by exploring changing rhythmic density and expressive microtiming for each of the players. However, relying on these single-track recordings of MFM's and CL's improvisations it was not possible to examine in further detail any micro-temporal information with precision. In order to do so, there was a need to obtain individual tracks for each of the musicians' raw sound productions, so as to pinpoint individual timing characteristics with precision and to investigate what happens between musicians by comparing single tracks together. Because good timing in this study occurred systematically with pulse, in passages where MFM referred to intense dialogue, and as timing at the pulse level of events has been shown to communicate expression to others, it was decided to investigate micro-temporal aspects of music-making over the course of a musical work with respect to good timing.

Finally, it must be mentioned that the recordings created were thoroughly enjoyable – it was a pleasure to listen to and watch MFM and CL's improvisations many times – but this thesis does not do justice to illustrating the technical, instrumental skill needed to make these recordings a decadent sonorous experience.

6

An acoustic analysis of jazz rhythm section performance: Negotiating pulse and form together in time.

1 Introduction

The study of the process of musical creation in a jazz context provides us with a rich source of information on the coordination of behaviours and ideas, on the sharing of expressive intentions and on the roots of human communication (Gratier, 2008; Schögler, 1999). Timing is often emphasized as being the most important framework for musical negotiation when jazz musicians discuss improvisational success (Monson, 1996). What is the acoustic basis of playing 'good time' together in jazz? This is the question at the heart of this investigation. It is addressed by comparing four versions of a musical composition performed by a jazz quartet for the recording of a studio album. The two rhythm section players (bassist and drummer) openly disagreed about the success of two of the four versions, and in the course of the argument the musicians repeatedly refer to problems with timing. The third version was unanimously rejected by the group and the last version was accepted by all the musicians and their producer as the 'keeper'. The aim of this study is to seek evidence, based on acoustic analyses of the musical tracks, that in the third version the rhythm section players were not able to maintain a sense of playing 'good time'. What is the musical evidence of differences between successful and unsuccessful versions? If musicians are able to feel implicitly that on one occasion the music works and on another it does not, we should be able to observe objective differences between them. This study then takes a situation familiar to any professional musician involved with 'making music', as a starting point for an empirical investigation into the timing processes underlying the experience of good time, which is fundamental for most improvised performance. The acoustic analyses presented focus on temporal negotiation at the pulse level and provide measures of local tempo, inter-musician timing and musical activity.

Jazz musicians have an incredibly heightened almost micro-auditory sensitivity to and control of musical timing for both expressive and communicative purposes, as well as great knowledge (often implicit) of such timing processes, as documented by the ethnomusicological research presented in Chapter 3. What is the acoustic nature of this shared and implicit know-how? How do musicians coordinate their individual ideas and purposefully negotiate their joint musical productions at a sound level?

In conventional jazz formations the most common description of playing music with groove makes reference to small-scale timing processes. Often, a soloist's timing has been studied relative to the rhythm section or some sort of reference beat. However, the timing of soloists' performance cannot simply be measured against the framework provided by the rhythm section, because rhythm section musicians are also actively shaping the musical performance. The nature of rhythm section negotiation at various levels of timing remains largely unknown. In chapter 3, I highlighted a debate between the rhythm section's role as either providing a strong, steady, isochronous pulse (providing stability), or as involving a malleable, subtly out-of-time pulse (conveying flexibility). In the rhythm section then, the relationship between stability and variability might provide an important cue to understanding good time. Must rhythm section members play steadily and precisely together, in order that soloing musicians be freely expressive around them, or must they play with flexibility in order for the music to groove?

In reference to creating a groove, one of the musicians Monson interviewed commented that "a lot of times it's a matter of just hitting the right tempo" (Michael Weiss, cited in Monson, 1996, p.68), and the association of tempo with groove or good time is certainly not new for jazz musicians. But whether this means that good time involves finding the right tempo and adhering to it, or whether it implies finding or *negotiating* the tempo over the course of musical play, whatever the resultant tempo may be, is unknown. Empirical investigation into the nature of tempo has shown that across musical performances small local tempo changes are common at specific moments to emphasize musical structure (Collier & Collier, 1994), by for example decelerating at the entrance of a particular soloist. On a larger scale, Collier and Collier (1994) found that for a large set of jazz recordings the final tempo varied by only 5% of the original, hinting at considerable tempo stability from beginning to end but missing the greater part of a piece's development. Rose's (1989) work confers that the on-going pulse (by comparing 8-bar sections) remains stable, despite deliberate micro-temporal deviations against the pulse on a medium (bar-length) scale. Reinholdsson (1998) also has shown that rhythm section musicians are perfectly capable of maintaining an isochronous pulse (whether it be before, on top of or behind the beat) if they chose to do so. However, the standard deviations of the rhythm section's changing local tempi in Ashley's (2002) studies have shown that even though performance might be steady *overall*, it is far from metronomic.

At the note-by-note scale, skilled rhythm-section players on average purposefully either push each others' beat, play on the beat or play behind it using very small deviations as they wish (Friberg & Sundström, 2002). We have also seen that Rose's (1989) musicians tended to sustain some beats and shorten others inside of each bar, depending on the musical piece, which indicates both departure from metronomic accuracy and that rhythm section instruments articulate their musical expression with respect to patterns specific to the musical idiom. Quantitatively, the inter-musician timing between rhythm section instruments has been shown to contain average differences of less than 20ms and more often than not, a bass' notes tend to arrive slightly after the drummer's (Friberg & Sundström, 2002; Rose, 1989). However, an additional influence which has been widely cited and demonstrated empirically by Progler (1995) is personal timing style – the way individual musicians tend to place notes on average before and/or after each other, such as Armstrong's 'behind the beat' rhythmic approach. Progler's (1995) findings suggest instead that rhythm section musicians do not necessarily play in a particular order, but that depending on their own inter-personal timing style they may play either systematically before or after the other musician. Progler's (1995) findings also indicate that timing between musicians is not as precise or tight as has been previously reported. Indeed, one of the musicians he studied tended to perform notes between 5ms and 120ms before the backing metronome (from Figure 2., p. 36).

A final cue to the joint production of good time in jazz rhythm section performance comes from our natural propensity to shape musical sounds over time. Schögler's (2003) studies of the development of intensity or loudness in musical performances revealed a larger, narrative-based level of variation, reflected in pervasive cycles of synchronous intensity peaks independent of musical structure. If we return then to more common practices using tempo and/or the timing of note onsets between players, it is crucial to investigate the range and development of these measures over the course of musical performance.

2 Defining the methodological framework

In several of the empirical studies mentioned, researchers have used existing commercial recordings, which can be both problematic for distinguishing individual musicians' performances (tracks are fused together) and provides the researcher with highly engineered or 'sculpted' performances. Live musical interactions, either in performances, jam-sessions or recording studio sessions, provide an ideal organic setting for the researcher and enable observation of the situation as musicians arrange it naturally. The best way to capture the raw sonorous interactions between musicians, is to study recordings of the performance without any post-production on the musical tracks. Secondly, it is important that the microphones used were positioned in such a way as to minimize as much inter-track bleed (sound from one microphone or musician leaking into the recording of another) as possible, in order to then have separate recordings for each musician with which to investigate the inter-personal aspects of musical interaction.

A second weakness in previous research is that researchers have focused on short musical excerpts, from which they generalise about 'groove-based music'. But we know from report-based studies that in live performance music does not always groove evenly and that the quality of groove itself is variable. For this reason, the current study was designed to investigate good time by, in some respects, working backwards. Instead of searching for the experience of good time in a new musical performance, we have taken music with 'known' timing: a live situation in which two of the group members argued about the temporal 'success' of different versions of the same song. We know from the musicians' verbal reports that one of the versions was unanimously disliked, one was a compromise, and two of the versions contained disputed degrees of good timing. These descriptions are then used as a starting point for an empirical investigation into the timing processes underlying the experience of good time. In other words, we ask which features of the musical sound-scape are most important for achieving the shared experience of good time and how one might look for indices of this process at a sound-level.

A third important methodological shortcoming of previous studies is that attention is often paid to the mean local tempi or mean timing discrepancies between musicians, but the development or progression of such variables over the course of the musical work is not taken into account. For this reason we also ask how such processes evolve throughout the musical piece and whether this developmental dimension is also important for achieving 'good time'. In order to approach these queries from a microanalytical perspective, it was first necessary to reflect upon a method of comparison between versions, and how these versions could be compared at different levels of timing. As most analytical methods which study the temporal features of a musical performance require obtaining information about when exactly the notes are played in time, one of the methodological issues concerned the nature of the beat itself.

2.1 Where is the beat? – Note onset detection

In order to investigate timing at the pulse level, it was necessary to define a note's onset in the musicians' sound production. Studies which discuss musical timing often do not include a description of the definitions used for onset detection, even though it is of crucial importance when conclusions are being drawn involving timing measures on the order of tens of milliseconds.

Onset detection is an active research area in the realm of signal processing (see Audio Onset Detection contest (MIREX), www.music-ir.org/mirex/wiki/2011:Main_Page). Approaches to onset detection can operate in the time domain, frequency domain, phase domain or complexity domain, and include looking for increases in spectral energy, changes in spectral energy distribution or phase and changes in detected pitch. Onset definitions also depend on the discipline in which they are employed, including those used in speech analysis, phonology, acoustics, musicological analysis and studies of expressive timing.

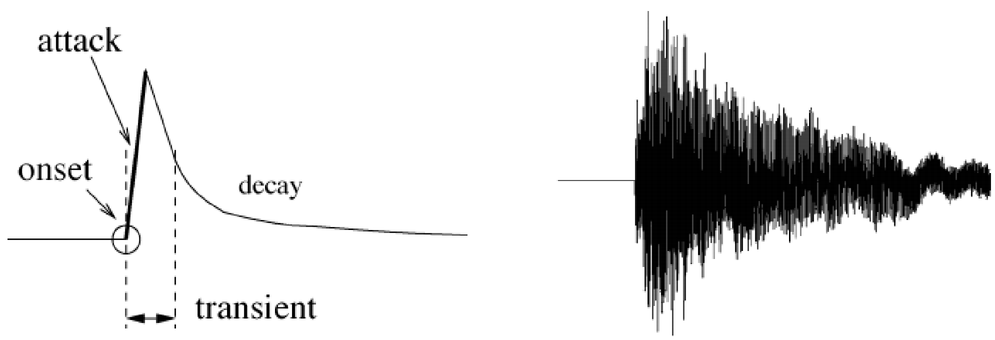


Figure 6(a): A computer-generated acoustic signal, and Figure 6(b): The soundwave of a naturalistic musical note.

With a simple computer-generated signal, its onset, attack and decay can be easily separated (Figure 6a), however for a live instrumental note (Figure 6b) these distinctions are less straightforward. Most people would agree that a musical note's onset is the point at which the event becomes audible, but the difficulty is in defining the meaning of audible in a musical context (Bilmes 1993). Does it refer to the sound's maximum increase in physical energy, or the peak firing rate of the cochlear nerve, or the perceptual attack time, or otherwise? Some researchers have chosen to use a 'perceptual' criterion to define the point of onset, referring to the moment of sound recognition by the ear. Rose (1989) describes his method of pinpointing tone onsets as the moment in time when the amplitude of a tone reaches a level approximately 15% below its maximum amplitude, found to be correlated with a perceptual beginning. Other researchers have favoured a 'mechanical' point of onset, referring to the first changes of energy in the signal itself (Rasch, 1979).

To cite a few of those definitions which have been applied in the study of timing in jazz settings: Bilmes (1993) suggests that a note's onset involves the point at which the slope of the short-time energy of the high-pass filtered signal reaches a peak; Collier and Collier's (2002a) definition refers to positive zero-going crossings at the points where the waveform becomes discernibly different from background noise; Dixon's (2001) definition involves peaks in the slope of the amplitude envelope; Ashley's (2002) tone onsets were defined as the "amplitude zero crossing most immediately preceding the beginning of the (quasi)periodic portion of the tone" (p. 315). However, there are few programs capable of automatically detecting a note's onset when applied to live instrumental recordings (rather than electronically-produced music). In 2001, Dixon commented that "to date, no algorithm has been developed which is capable of reliably extracting the onset times of all musical notes from audio data" (p. 44), suggesting that instead researchers should rely on hand-labeled or at least hand-corrected data for evaluation purposes. Even if a computer program is used to signal note onsets, future studies will have to then systematically verify each placement by inspecting sound files by eye and ear and applying one of the aforementioned definitions.

There are two additional areas of ambiguity when marking note onsets (by eye and ear or otherwise). The first refers to the nature of the attack itself, or the way in which a note is 'placed' by an instrument: note contacts which are 'soft' or 'hard' are simply two extremes of a continuous scale of effort or expression (Schögler, 2002). Benadon (2006) suggests that it can be easier to identify an onset in staccato playing, but legato playing involves an element of indistinctness when the pitch changes from one note to the next. Moreover, the form of a note's beginning can also vary from instrument to instrument, for example a wind instrument's soft blow tends to have a longer attack time than the crisp tap of a cymbal. This is why it is easier to determine the attack time in percussive music because there is less room for error: "relative to other musical instruments, the time between zero and maximum energy of a percussive musical event is almost instantaneous" (Bilmes, 1993, p.

25). While this measurement may seem minute in scope (around 5ms), it can become a significant contribution because the magnitude of the discrepancy increases proportionally with tempo (Benadon, 2006).

The second area of ambiguity makes reference to the difficulty of separating technical 'error' (slipping on a string, catching the edge of a cymbal instead of the centre) from musical mistakes (wrong notes) and from intended displacement when playing a note early or late from the beat itself. But because it has been shown that musicians are perfectly capable of playing on the beat to within 5ms (Friberg & Sundström, 2002; Reinholdsson, 1998), I believe it is important to assume that musicians are aware of this aural phenomenon and control their movements with this in mind, anticipating the extra time needed for their specific instrument. Different instruments may be likened to different manual car makes each with subtly different clutch points, and we must believe that musicians know their instrument and how to 'drive' it with extreme sensitivity.

The following section introduces the experimental methodology adopted and describes in detail the definition used for finding a note's onset. It is hoped that the results of this study will provide further insight into the ways in which time is mastered in the rhythm section to serve both communication and aesthetic expression in jazz musician interaction.

3 Methods: A technique for investigating 'good time' in the rhythm section.

We have decided essentially to further investigate expressive microtiming in the rhythm section, adapting our methods to consider music-making as a dynamic process of ongoing communication and mutual negotiation between individuals. Three variables are used to gain insight into these processes of inter-musician negotiation and they are studied within a developmental framework. The 3 variables are developed from previous studies: The different tempi employed (Collier & Collier, 1994) and their development (changes in local tempi); a measure of number of notes played (Goebl & Palmer, 2009) or musical activity; and the inter-musician timing – micro-temporal differences between attack onsets on the same beat (Friberg & Sundström, 2002 *(ensemble timing)*; Goebl & Palmer, 2009 *(timing synchronisation)*; Keil, 1987 *(participatory discrepancies)*; Keller & Repp, 2008 *(inter-agent coordination)*; Rose, 1989 *(mean latency values)*). However, timing relative to an absolute or mechanically 'perfect' execution was not investigated (Ashley, 2002; Reinholdsson, 1998), as our approach was to develop variables applicable to an ecological situation, one in which natural tendencies to speed up and to divert from mechanical precision prevail. In this respect, there was no 'reference' beat to which comparisons were made, either using a perfect performance, by using a metronome or by measuring the timing of one musician with respect to the other.

In order to have a representation of the development of these tendencies over the course of a musical piece, we chose to measure each variable periodically, every 8 bars of music. To investigate *good time*, that powerful engaging quality of music that comes about when musicians collaborate together and feel that they are collaborating well, we investigated these variables in each of the four versions of the song with and without good time as experienced by the music-makers themselves.

The main research question guiding this study was: What does playing well in time together in live jazz rhythm section performance resemble over the course of a musical piece? The aim of this study was to investigate the dynamics of musical interaction in a natural setting by exploring what musicians refer to as playing 'good time' together at the pulse level in terms of observable and measureable acoustic phenomena. We do not impose our own criteria, our starting point is the musicians' own spontaneous appraisal of their performance. We chose to look for similarities and differences between each of four versions of the same musical piece in relation to three variables: local tempo development, inter-musician timing and musical activity. The musicians' representations of successful performance are assumed to be based on the nature of their musical collaboration over the extent of the musical work. Because the third version was unanimously considered a 'reject' in terms of this jazz ensemble's musical ideal, we seek quantitative evidence in the third version's sound production that the rhythm section players were not able to achieve the quality of coordination that produces 'good time'.

3.1 Data collection

The audio tracks from which the data for this study were obtained belong to a large corpus of recordings made in a real-life studio setting. The Paris-based jazz quartet called Less is More (referred to as LIM from now on) had invited researchers from the Psychomuse Laboratory of the Université Paris Ouest Nanterre La Défense to document the entire process of recording an album in a professional sound studio (a study that was set up by Maya Gratier). Studio settings permit the researcher to have an acoustically isolated recording of each individual musician (separated by windowed walls) without completely restraining the musicians from how they would normally play together (being able to see and hear each other). The entire recording situation was filmed over a period of four days using two video cameras and a minidisc recorder. Live musical performances were recorded as well as any intermittent talk between musicians in the studio and prolonged conversational exchanges in the control room. Of particular interest were those conversations that occurred between the musicians during listening sessions between takes in the control room. The idea to compare the rhythm section tracks on one of the songs performed for the recording of the album arose from a qualitative study of one of these conversations in which a disagreement regarding 'good time' was manifest (Gratier & Stevanovic, 2008). Original, un-engineered Protools tracks of all the takes for all the songs were obtained from the sound engineer with signed consent forms from the quartet members. Thus, separate tracks were obtained for each instrument (guitar, saxophone, drum set and double bass), including multiple tracks for the drum set. Sound files were in .aiff format sampled at 44.1kHz.

The present study is based on the tracks from each of four versions of a song called "Ten", composed by leader and double-bass player of the quartet. After the first 'take' of this song, the drummer and double bass player expressed disagreement about the success of each version, mentioning in particular difficulties of 'being together in time'. Two of these tracks, the double bass's microphone, and the left overhead microphone to the drum set, were used for an acoustic analysis of the musical interactions between the two proponents of the argument. The left overhead microphone was chosen because in jazz, the limb employed by the drummer as his dominant 'time-keeper' usually plays the ride cymbal, but in this composition the drummer chose to use brushes on the snare, which was most effectively picked-up by this microphone.

3.2 Description of the composition

Four versions of the contemporary jazz composition "Ten", written by the bassist and bandleader (Manu Marchès, 2008), were performed and each was examined in detail in this study. Because each of the versions was recorded consecutively in a studio setting, with the aim of producing a track worthy of inclusion on the forthcoming album, all four versions were more similar in terms of their 'organisation' than what would be found in live concert or practice settings. Players used the same instrumental set-up (drums, bass, guitar and saxophone), the same sequence of playing techniques throughout the song (for example the drummer always plays with brushes), and much of the musical structure was defined before the musicians began to play. The musicians decided, mostly dependent on the desires of the bassist (and composer of the piece), to play two cycles of the 32-bar theme with a guitar solo (without the saxophone), then introduce the theme's melody with the saxophone for one cycle, followed by a saxophone solo over two or more theme cycles (Figure 7). In the last 8 bars of the last cycle, the saxophone returned to the corresponding last part of the theme's melody. The 32-bar theme (harmonic chord progression and melody) is shown in notated form in Figure 8, however each of the jazz musicians took extended liberties in their interpretations of the melody. No tempo marking was written on this score, but before each take, it was the bassist who decided when and how to start playing, sounding out the introductory tempo by clicking and/or speaking.

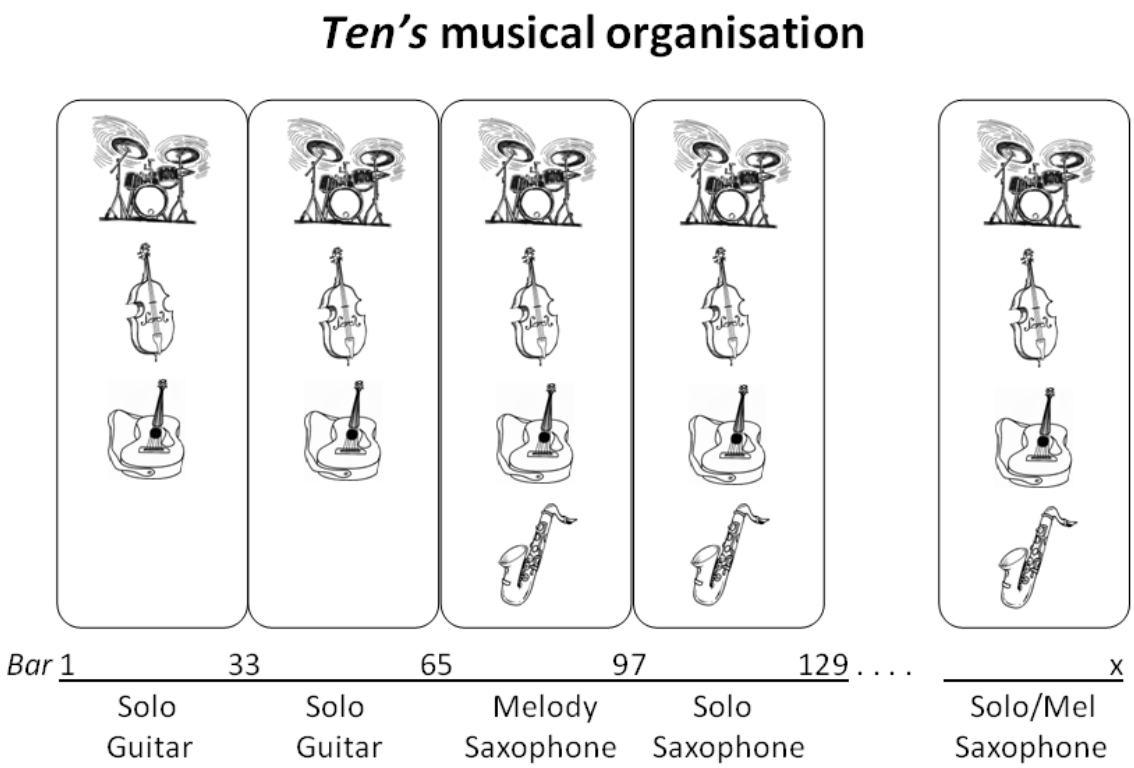


Figure 7: Ten's musical organisation defined pre-performance by the group.

Figure 8: Ten's 32-bar theme, including harmonic chord progression and melody. Courtesy of Manu Marchès, 2008.

3.3 Description of the situation

In the recording studio each musician was installed in a separate sound-isolating booth with windows enabling visual contact with the others. Microphones were positioned in each room and players wore headphones through which they heard the group's production including themselves.

The recording of "Ten" lasted one morning and a little of the same afternoon. To summarise the argument: The bassist preferred Version 1 and disliked Version 2. The drummer preferred Version 2 and disliked Version 1. Version 3 was unanimously rejected, and the fourth and final version was for each of the musicians the compromise – the one to keep. However, it should be noted that this version is not necessarily the 'best' or 'ideal', but rather a compromise in terms of aesthetics, ideas and sentiment at that precise moment in the recording session.

It should be noted that musical performance in a recording studio is a unique situation, subtly different from a concert performance, rehearsal or casual jam-session. Musicians are trying to record something 'ideal' – a 'polished' representation of how they play, as their production creates a physical trace to be kept for years to come. At the same time, the nature of jazz means that the musicians do not play in exactly the same way for each 'take' or repetition, as they aim to improvise collaboratively in each performance. Of course, musicians keep various melodic and rhythmic sequences 'up their sleeves', and have practiced extensively in order to be at the height of their capacities. But there is a real clash of interests in the music-making process in the studio, because musicians are at once aiming to be fully creative and free and aiming to perfect their musical play.

3.4 Acoustic analysis of the Protools tracks

To obtain timing measures at the pulse level, it was necessary to systematically define the attack onsets in both the double bass and snare drum sound waves. For this study, we used a combination of the definitions previously adopted by two studies of timing in jazz. Ashley (2002) and Collier and Collier (2002a) both defined attack onsets as positive-going amplitude zero crossings most immediately preceding the beginning of the (quasi)periodic portion of the tone.

Audio recordings were analysed using the program *Audiosculpt*, to which I was granted access during an internship at IRCAM, Centre Pompidou. *Audiosculpt* produced waveforms for each track, representing amplitude in relation to time (milliseconds), and had the advantage of possessing a function for extracting attack onsets and applying subsequently moveable markers to their exact position in time. However it was then necessary to use the ear and eye to make adjustments to the markers' placements, using the attack-onset definition previously described, as not all attack onsets were successfully recognised by the program's function. In order to measure reliability, as it was at the discretion of the researcher to make final adjustments to the marker's placement, a second researcher was asked to make these adjustments for 32 bars of music: interrater agreement was found to be within 2ms for 84% of the adjustments made, hence it was decided that the first researcher's adjustments could be used with confidence. Consequently, lists of the markers' placements (attack onsets) were exported, translated into text and manipulated using Microsoft Excel.

3.5 Variables

1) Local tempo

For the analysis of the different local tempi or changes in speed throughout each of the four versions, the attack onsets of the notes played on the first beat of every 8 bars were noted, and the local tempo was then calculated using the difference between two attack onsets, to give a measure of tempo-per-8-bars. In other words, I calculated the inter-onset interval (IOI) between attacks of beat 1 of passage 1 and beat 1 of passage 2, and used this to determine a local tempo for that 8-bar passage. The formula used to calculate tempo-per-8-bars (t) is the following: t(beats-per-minute, beat=minim) = $(1/((x(s)/8)/3))*60$, where x = the IOI between the attack onsets of the notes played on the first beat of every 8 bars, and every bar contained 3 minims (the time signature was 6/4). For each of the versions, the two musicians' local tempi rendered the same graphs at this scale, so only one was used (the bassist's).

2) Inter-musician timing

Inter-musician timing between the bassist and drummer was calculated using the proximity and deviation of the attack onsets of the same notes played by each musician at the beginning of every 8 bars (Figure 9). If both musicians played at exactly the same moment their asynchrony measurement would be 0, if the drummer played the same note *before* the bassist, the measure was negative, and if he played *after* the bassist the measure was positive.

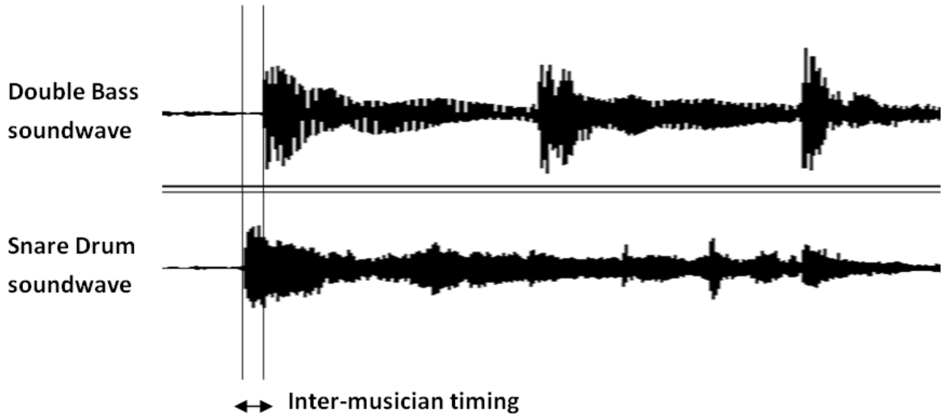


Figure 9: Calculation of the inter-musician timing present between double bass and snare drum sound waves (x=time, y=amplitude).

3) Musical activity

The method used to determine a measure of musical activity in each version was to attribute markers to every note played, down to the smallest quaver triplet, and to count the number of markers per 8 bars of music. For this variable however, only the double bass's performance could be determined, as placing markers on the snare drum's shorter brush strokes proved too imprecise an exercise. This is because of the nature of using brushes to articulate sounds, by 'swishing' or 'brushing' the snare rather than tapping it, unfortunately rendering shorter notes inseparable (by the computer's algorithm and by eye and ear) compared to the more salient notes produced by a stick tapping a ride cymbal for example. If, for the double bass sound waves, a note's existence was not certain (because of the note being inseparable from another or note quality being too vague), it was omitted from analyses.

For each of the four versions, developmental curves of each of the three variables – local tempo, inter-musician timing and double bass activity – were graphed over time, and were superimposed with the musical structure of the song.

3.6 Hypotheses

Because the third version was decidedly unrepresentative of the musicians' temporal ideal – they all tacitly agreed that this version was not even worth discussing – this version should be quantitatively different from the other three. It was hypothesised that each of the variables (local tempo, inter-musician timing and musical activity of the bassist) would contribute to playing well together in time, and there would be differences between the four versions in terms of these variables. We propose that good time is based on a dynamic negotiation of the pulse between rhythm section members. This will involve more flexibility than previously established, because of the live nature of the recordings (no post-production on tracks, no metronome) and because of the anecdotal evidence of rhythm section musicians themselves (Berliner, 1994; Keil, 1994; Monson, 1996). We also propose that the development of each variable over the course of the musical work will influence the relative success of the versions, as good time is essentially a social process involving experience over time.

4 Results

Both similarities and differences were found between the four versions studied. To begin with, Figure 10 displays amplitude with respect to time giving an overall view of sound production. All tracks were collapsed (drums, bass, guitar & saxophone) into one track for each version, but no attempt was made to normalise or balance the tracks (to eliminate clipping for example) because we wanted a raw representation of their sound production. Each version showed slightly different sound amplitude development – the way each version grew and diminished in intensity throughout the piece – and it might be said speculatively that the fourth version contains the most linear or smooth increase in intensity, culminating in much greater intensity only at the end of the musical piece, however amplitude envelope development was not investigated statistically.

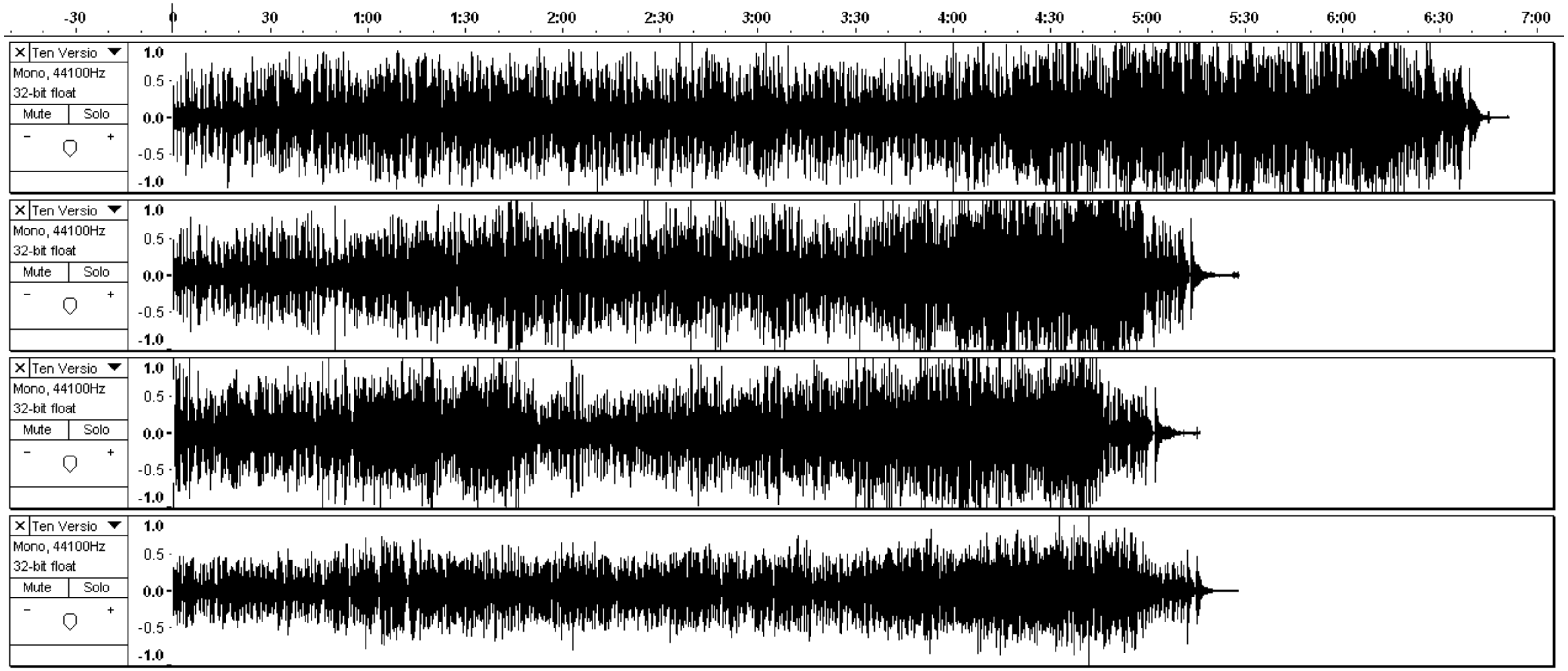


Figure 10: A view of sound production showing amplitude with respect to time (m:ss) using the program *Audacity*. All tracks were collapsed (drums, bass, guitar & saxophone) into one track for each version, but no attempt was made to normalise or balance the tracks (to eliminate clipping for example) because we wanted a raw representation of their sound production. All tracks included 7 Drum kit tracks (Overhead left (OverL), Overhead Right (OverR), Snare Drum (Sn), Bass Drum (BD), Hihat (HH), Timp Drum 1 (T1), Timp Drum 2 (T2)), 3 Double Bass tracks (Contrebasse 1 (CB1), Contrebasse 2 (CB2), Contrebasse 3 (CB3)), 1 Guitar track (Guitare (GT)) and 1 Saxophone track (Saxophone (Sax)).

The lengths of each of version of 'Ten' were (1-4): 6min39s, 5min13s, 5min02s, 5min15s respectively. Its musical organisation with section lengths is shown in Figure 11. Because of final note lengthening, it is difficult to say when exactly the sounds end and the music is over: here the end of the piece was defined as each version's last note's onset with an additional 5 seconds of note decay. The musicians adhered to the organisation decided upon pre-performance: the only version that differed slightly from this organisation was the first, in which three saxophone cycles were played instead of two. In other words, the musicians tacitly decided in the course of their musical play (from the second version onwards) that they would play only 5 cycles of the theme and that the whole performance should last just over 5minutes.

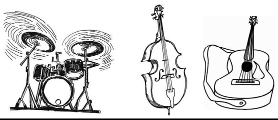
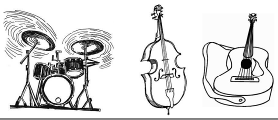
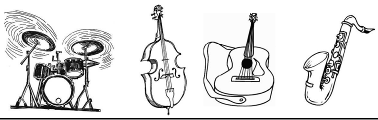
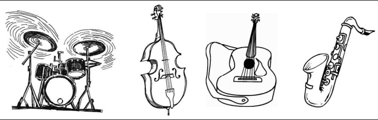
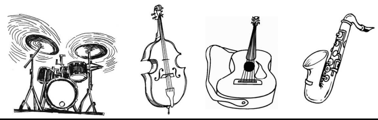
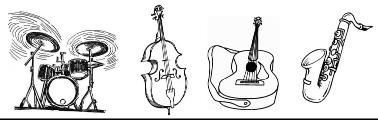
***Ten's* musical performance** **with length of sections (m:ss.0)**		**VERSION 1**	**VERSION 2**	**VERSION 3**	**VERSION 4**
Guitar solo (32 bars)		01:09.6	01:04.0	01:01.8	01:04.7
Guitar solo 2 (32 bars)		01:06.7	01:02.8	00:59.2	01:03.1
Melody entrance by Saxophone (32 bars)		01:07.5	01:03.8	01:01.7	01:04.3
Saxophone solo (32 bars)		01:07.9	01:01.9	01:00.2	01:02.3
Saxophone solo 2 (32 bars)		01:04.4	01:00.7	00:59.3	01:00.6
Saxophone solo 3 (32 bars) *(Version 1 only)*		01:02.6			
Total lengths		06:38.7	05:13.2	05:02.2	05:15.0

Figure 11: Ten's musical performance with length of theme sections (m:ss.0).

4.1 Local tempo

The average local tempo for each version (1-4) was 85.91, 91.36, 94.83, and 90.57bpm. The musicians played relatively slowly to begin with, then in the second version they played with a slightly faster tempo, in the third they played faster still and in the fourth they played at a roughly similar pace to the second version. A one-way Anova showed that the versions differed significantly in terms of this variable ($F(3,80)=28.258$, $p<0.01$); Post-hoc comparisons revealed that mean local tempo for versions 1 and 3 were significantly different from all other versions (version 1 was slower and version 3 was faster)(Test Tukey HSD $p<0.01$) but versions 2 and 4 were not significantly different from each other. An analysis of each version's different local tempi changes revealed unexpected and interesting tendencies (Figure 12). Firstly, the extent of local tempo change from beginning to end is quite noticeable – the last local tempo calculated changed by between 11% (versions 2 and 3) and 24% (version 1) of the first. Qualitatively if one listened for a few seconds to an excerpt at the original speed and switched to the final speed the difference would be perceptibly startling.

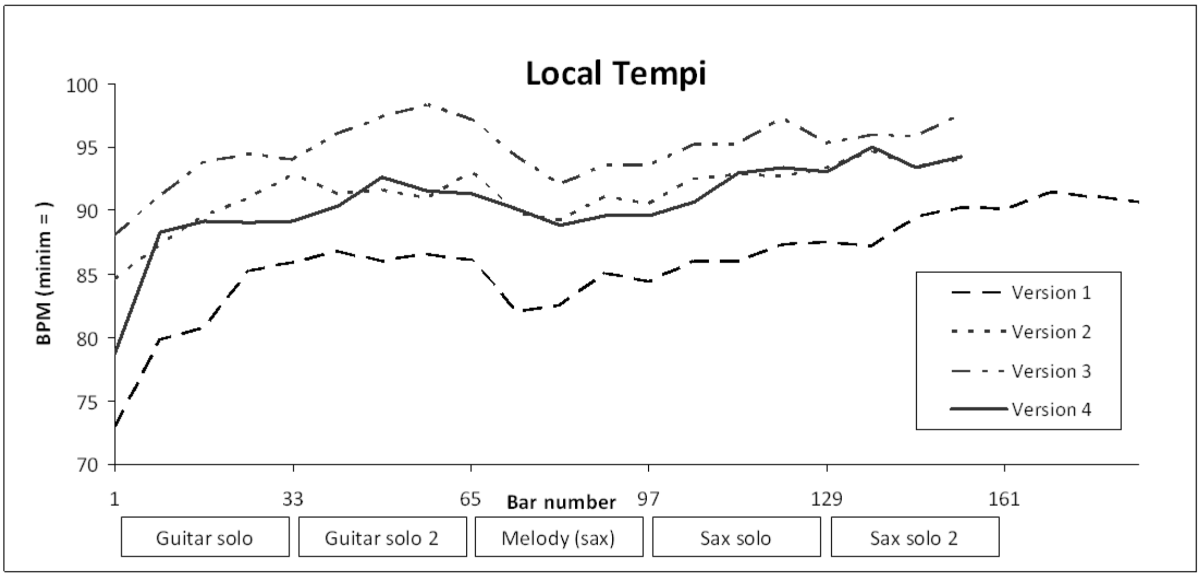


Figure 12: Development of local tempi performed by the double bass player for each of the four versions, where local tempi (minims-per-minute) are graphed in relation to bar number. For each of the versions, the drummer's local tempi rendered graphs almost exactly the same as those of the bassist's at this scale, so were not shown.

Secondly, the shapes of each curve (local tempo development) were exceptionally consistent. In each version, there was a tendency to accelerate progressively over the course of the song in two parts: an initial curve that concludes at the introduction of the theme's melody (bars 65-96), and a second curve until the end of the song. This development suggests that there is a clear link between the musical structure of this composition and its changes in speed over time. Two by two correlations between versions confirmed this tendency: there was a strong correlation between the shape or form of the dynamic local tempo curves of each of the four versions performed (R values were between 0.81 and 0.94): a common dynamic trajectory of accelerations and decelerations in time. The only version which deviated slightly from this trajectory was the third version, in which considerable acceleration occurs early in the musical work: the fastest local tempo at 98.4bpm occurs between bars 49 and 57, but in all other versions the fastest local tempo performed within a version occurred near the end of the musical piece. A second point to note with respect to the progression of local tempo is that small cycles of local tempo – faster and slower – were apparent for the entirety of each version.

4.2 Inter-musician timing

The first point to note with regards to analyses of the inter-musician timing discrepancies is the sheer magnitude and extent of asynchrony present (Table 5).

Inter-musician timing (ms)	Version 1	Version 2	Version 3	Version 4
Maxima (-) *(Drummer ahead)*	-66.19	-149.97	-69.54	-128.27
Minima	3.76	-1.62	-0.67	5.39
Maxima (+) *(Bassist ahead)*	114.06	133.61	85.66	53.30
Mean	10.18	15.98	20.88	-12.35

Table 5: Table showing the range of inter-musician timing discrepancies in milliseconds, for each of the versions 1-4. A positive figure indicates the bassist was ahead of the drummer in time, and vice versa.

The range of timing discrepancies present was between -150ms and +134ms, indicating significant variability in the size and *direction* of the sound gaps performed by the rhythm section players. As a reference, the musical significance of the size of the larger asynchronies (~100ms) is to consider a musician playing one triplet quaver ahead of or behind the other (at roughly 85bpm). The average size of asynchrony between bassist and drummer, where all figures were considered either absolute (quantity) or as positive and negative (direction), are shown in Table 6 below. Despite there being slightly greater asynchrony in the second version these averages did not differ significantly.

	Quantity Absolute inter-musician timing (ms)			**Direction** Inter-musician timing +/- (ms)		
Version	**Mean**	**SD**	**Range**	**Mean**	**SD**	**Range**
1	32.50	26.87	110.30	10.18	41.43	180.24
2	53.38	44.47	148.35	15.98	39.91	283.57
3	37.98	27.28	84.99	20.88	40.85	155.20
4	33.03	29.74	128.27	-12.35	33.99	181.57

Table 6: Mean, standard deviation and range of the quantities (absolute) and directions (+/-) of inter-musician timing present in each of the four versions performed. (note that a positive figure indicates a tendency for the bassist to play ahead of the drummer in time, and vice versa).

Comparing timing averages across the 4 versions, the small difference between versions only approached significance ($F(3)=1.737$, $p=0.16$) due to the large variation in size of asynchrony present. However, in the third version, the bassist was on average playing considerably ahead of the drummer and the fourth version is the only version in which the bassist plays on average behind the drummer. Despite the variability of inter-musician timing present, the averages are relatively small, meaning that the quantities often lie in both directions. To test this quantitatively, a one-sample t-test comparing timing in each version to 0ms (considering direction), revealed that only version 3 had timing that was significantly different from 0ms ($t(19)=2.199$, $p=0.04$): the bassist was significantly more often ahead of the drummer in version 3. The other versions contained an average that was not significantly different from 0ms, meaning that on average they played ahead and behind in equal amounts. This implies that if one musician performs ahead of the other, he will then be sure to play equally behind the other's performance in time, such that the mean difference comes close to zero: a kind of respectful balance in temporal turn-taking.

Cycles of synchrony – moments in the piece where the bassist played ahead of the beat, followed by moments where the drummer played ahead – were evident across each version, which provide further support for the idea of continued temporal and mutual negotiation and concession (Figure 13). The development of timing revealed an interesting tendency, albeit interpretative: the cycles of synchrony seemed to be linked to musical structure. The direction of inter-musician timing changed systematically throughout the piece, in relation to each group of 8 bars (where each measure was taken). The effect is particularly salient at the introduction of the theme's melody by the saxophonist (bars 65-96): in each of the four versions at the first note played while the melody was being introduced (bar 65), the bassist was a little ahead of the drummer, 8 bars later the drummer was ahead of the bassist, 8 bars later the bassist was ahead, 8 bars later again he was behind.

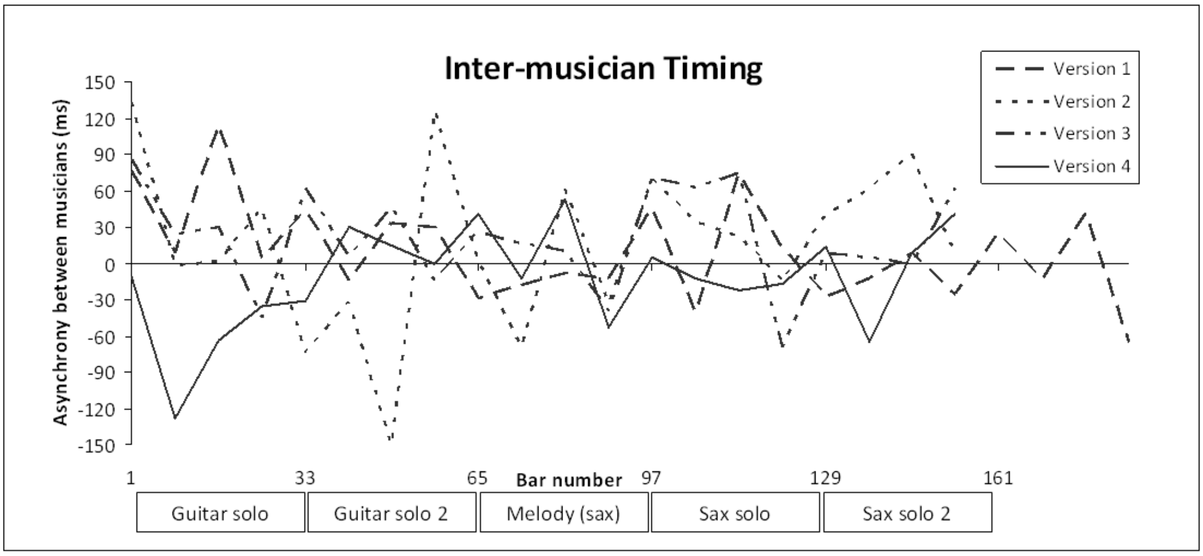


Figure 13: Inter-musician timing development between double bass and snare drum in each of the four versions performed, as represented by the inter-onset intervals between attack onsets measured at 8-bar intervals.

4.3 Musical activity

The four versions comprised very similar quantities of average bassist activity (versions 1-4): 27.88, 27.35, 25.80 and 25.45 notes per 8 bars. There were no significant differences found between versions in terms of this variable ($F(3)=0.839$, $p=0.476$), so the rejection of version three was not affected by the amount of musical activity at play. However the analyses of activity over time revealed again, cycles of activity present – bars filled with notes and subsequent bars relatively sparse – in each of the four versions and throughout the extent of musical play (Figure 14).

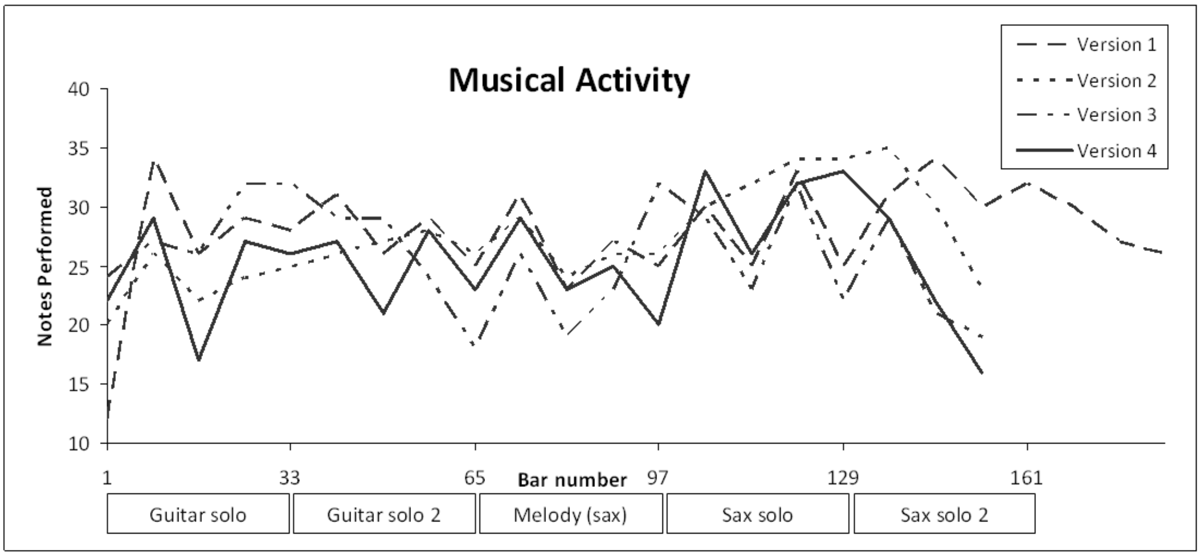


Figure 14: Musical activity of the double bass player's performance in each of the four versions, as represented by the number of notes played per 8 bars of music.

The analyses of activity development also revealed interesting and interpretative tendencies: musical structure seems to specify or influence in some way the amount of activity produced by the bassist. Whether there was an increase or decrease in activity relative to a particular moment in the musical work remained similar across versions. In other words, in bars 1-8 and 17-24 of each theme cycle, there were fewer notes played, and in bars 9-16 and 25-32 of each theme cycle, there were more notes played. Because of the improvisational nature of jazz performance the amount of notes to be played in each bar was not specified, which implies that it was not the musical score per se which defined the amount of activity but the bassist's interpretation of the way to play in relation to divisions of the musical theme. Again this feature seems particularly salient in the cycle in which the theme's melody was introduced (bars 65-96).

5 Discussion

We know that good time or grooving together does not come about by simply adhering to some common time signature: the common time feel of 'grooving' is collaboratively created and maintained through purposeful negotiation at various levels of musical timing.

In this study we have quantitatively distinguished four versions of one song in terms of mean local tempo, local tempo curve development and mean inter-musician timing, but not in terms of mean activity. These results show that it is possible to distinguish different versions of the same song at the pulse level, thereby documenting acoustic indices of good time. Why do the musicians reject the third version? The first part of this section addresses this question by describing the differences found between the third and the three other versions in terms of local tempo, tempo development and inter-musician timing. The second part of this section addresses the similarities between each of the four versions, which present and confirm general relationships between the three variables and musical structure, and have uncovered interesting tendencies in musical play.

5.1 Differences between versions

There are various reasons why musicians might dispute the temporal quality or perfection of their performances, but we have identified three plausible contributing factors. Firstly, version three was performed considerably faster than the three other versions. Of course the first version also contained a significantly different (slower) average tempo, so to some extent playing good time together and 'hitting' the right tempo involves playing in general neither too fast nor too slowly in relation to each musical piece. More importantly, the shape of the rejected version's local tempi development differed significantly from the other versions: in this version the musicians accelerated and arrived at their fastest local tempo before the introduction of the melodic theme. Could it then be that in this version, the development of musical energy was flawed? Musicians clearly define playing well together in terms of a specific dynamic trajectory of accelerations and decelerations in time, and 'hitting' the fastest tempo at a mutually-negotiated moment in this musical piece is perhaps of central importance.

Thirdly, the extent to which inter-musician timing, on a large scale, contributes to the musicians' understanding of playing well together in time, is debatable. There was no evidence that the two argument's authors were more synchronous in the first, second and fourth versions, which might have been predicted as a sign of 'being together in time'. Nor can we conclude that less synchrony, playing 'out of time' occurred more often in these renderings. However, the 3rd version was the only version with a timing average significantly different from 0ms. Despite the range of sound gaps left between musicians, the only version in which the musicians did not take turns at performing ahead of and behind each other in equal amounts was the third version, and in each of the three other versions the mean differences came very close to zero. This implies that it is not so much the quantities of inter-musician timing which directly influence musicians' impressions of good timing, but the relative balance of temporal leadership, reflecting fairness in their temporal turn-taking.

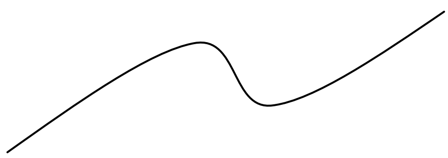
The hypothesis that the bassist's musical activity variable on a large scale would contribute to distinguishing successful from unsuccessful versions, was not supported. Future studies are needed to investigate the drummer's activity in itself and in relation to that of the double bassist, in order to fully explore this variable with respect to good timing in the rhythm section. We may then be able to answer the question: does collaboration with good time imply playing 'interestingly' together, with similar amounts of activity at the same time, or by giving each other turns (as the inter-musician timing result would tend to predict)?

5.2 Similarities between versions

The similarities found between versions may reflect something of all improvisatory music practices, the way in which collaborating musicians play with or without their aesthetic ideals and good time having been achieved. One of the constants discovered across versions and which distinguishes our approach from that of previous research is the extent of local tempo change or drift present. For Collier & Collier (1994) local tempo in jazz recordings changed only slightly (<5%) and for Friberg and Sundström (2002) is changed between 3 and 16%, whereas for the performance in this study, in which no metronome was used to guide the musicians' play, the final local tempo changed by between 11% and 24% of the original. Some might say that European classical music performance does not fall into the realm of groove-based music such as jazz (for such analyses) because of its reliance on local tempo variation for expressive purposes (Iyer, 2002), and inversely that jazz can be differentiated from classical practices because of it's temporal stability. We might think, or like to think that jazz performance is less forgiving in terms of local tempo variation than in classical Western music's instances of *rubati*. But, as is illustrated in this study, jazz performance also involves considerable local tempo variation and development.

Amidst these tempi changes, we reaffirm the findings of Collier & Collier (1994) that tempi are slightly varied with respect to certain elements of musical structure or organisation. In each of the versions recorded, to a different extent, local tempo, timing and double bass activity were used to convey musical structure to themselves, their collaborators and to their (imagined) audiences. The most clear indication of this is the link between musical structure and the development of local tempo: at the introduction of the theme's melody (bar 65), the musicians implicitly know to slow down; the rest of the time the local tempi employed become faster and faster, creating a distinct local tempo trajectory.

Indeed, despite the general tempo having been agreed upon pre-performance (the bassist sounding it out before each version), part of the musical process clearly involves dynamic temporal development in the course of musical play. In other words, musicians define playing well together in terms of a mutually-established local tempo trajectory that best suits the musical piece. It is not so much 'hitting' the right tempo and sticking fastidiously to it, or even departing from that tempo and returning to it; for this musical piece at least it involves something that might be described as follows. Gradual acceleration until a 'velocity high point', deceleration until a tempo which is roughly half-way between the original and the high point (a 'slow velocity turn point'), and then a second period of acceleration until the velocity climax (see also Fig. 4).



Because the music was organised into three sections – solo, melody, solo – this organisation is clearly influencing the shape of local tempo development, but it is surely not the only influence. Further studies are needed to investigate such tendencies in musical works with different organisation, but it seems intuitive that such shapes or forms are sought after in collaborative musical creation.

Amidst large scale development of narrative intent also exists smaller micro-variation of musicians' moment-to-moment engagement and collaboration. Continued cycles or circular changes of local tempo, inter-musician timing, and double bass activity were found in each of the four versions, throughout the extent of musical play. With respect to inter-musician timing, not only do musicians leave considerable sound gaps between them, but they do so alternating with timing leadership: playing ahead of and behind the co-constructed beat while the other does the opposite.

These results show that it is possible to distinguish different versions of the same song at the pulse level, thereby documenting acoustic indices of good time. Two key findings were that good timing involves both a mutually-established local tempo trajectory that best suits this musical piece, and continued mutual negotiation and concession at the pulse level. But if we are to draw conclusions about meaning-making in musical exchange, we should also investigate what qualities of musicians' sound productions the audience can hear. Can 'outsiders' – music listeners with limited experience of jazz – hear when two musicians are playing 'good time' together, and when they are 'out of time'?

Acknowledgments

The microanalyses for this research were performed thanks to invaluable input from researchers from the "Analyses of Musical Practices" research group at IRCAM (Institute of Acoustical and Musical Research and Coordination, Pompidou Centre), Paris. Special thanks are addressed to Nicolas Donin, Samuel Goldszmidt and Leigh Smith.

7

An experimental investigation of inter-musician timing

1 Introduction

Micro-timing variations can be the result of various processes at play, conscious or otherwise, including sensory-motor processes linking brain, body and instrument, musical culture and style, instrumental roles, personality, performance context (live, rehearsal), acoustic conditions, and temporal discrepancies which are used to communicate something to the other musicians. The two previous chapters have focused on performance characteristics, how musicians produce a musical work together, but there is also the mirror to performance: how listeners perceive the music, or rather create their perception of the work. The audience is also involved in the collective experience of groove in musical performance, and musicians actively communicate with their audiences. Groove itself has been described by Keil (1994) as a performance's ability to engage both players and audience in a musical event. If we are to draw conclusions about meaning-making in musical exchange, we should also investigate what qualities of musicians' sound productions the audience can hear. This chapter asks: can 'outsiders' – music listeners with limited experience of jazz – hear when two musicians are playing 'good time' together, and when they are 'out of time'?

In music performance in general, given that musicians systematically perform with timing variations, it is natural to predict that listeners will also expect to hear such variations. When forming aesthetic judgments, anecdotally, music without expressive timing generally sounds dull, and music with unusual or random timing sounds bad or wrong (Repp, 1998b). Most music listeners would agree with this notion, at least if they are familiar with the musical style and the general principles underlying expressive timing. When Madison (2006) studied listeners' experiences of groove, he asked participants to make ratings of groove in different jazz and dance music samples, and found that inter-individual participants' ratings were remarkably consistent. Listeners agree about whether music 'grooves' or not, but the study does not assume which properties of the music have brought about the consensus. In Chapter 6 I have shown that one of the acoustic indices of the experience of *good time* manifest in performance involves subtleties in inter-musician timing. If musicians create and negotiate good time in part through the use of timing discrepancies between them, and playing good time is about engaging the audience and 'saying something' to them (and to each other), then the audience should be able to hear this subtle manipulation of inter-musician timing negotiation at the pulse level. Musicians clearly leave significant sound gaps between them to 'say something' in their musical collaborations to each other and to their audiences. To what extent do auditors with limited experience of jazz hear what is being said?

There are two main questions guiding the two experiments presented in this chapter. The first inquires about how outsiders perceive the quantities and placement of inter-musician timing differences between two rhythm section musicians in the course of live performance. Do listeners prefer music with perfect temporal synchrony between players, do they prefer natural, imperfect synchrony (repeating the studies of Bilmes, 1993 and Busse, 2002 but with an ecologically-grounded methodology), or do they prefer other forms of inter-musician timing? A second question asks what is the range of inter-musician asynchrony which is musically acceptable to outsiders? In asking this question we are essentially searching for the just noticeable difference between music with and without perceived 'good timing' between musicians.

There have been several empirical studies investigating the perception of expressive micro-timing variations in performance (Bilmes, 1993; Busse, 2002; Butterfield, 2010; Hirsh, 1959; Honing, 2006; Madison, 2006; Repp, 1992, 1998c, 1999a; Vernon, 1937). Subtle yet tangible timing differences exist between what is notated and what is created in performance, and it has been shown that music listeners of varied experience are able to listen out for such differences in strictly experimental settings. A central concern of this thesis however was to avoid the use of synthesised-from-scratch recordings as have been used in previous studies, favouring instead an ecological musical situation. In this respect an effort was made to provide a setting retaining as many naturally-occurring musical qualities as possible, which meant using raw instrumental recordings and manipulating only the variable of interest. In addition, a live performance was chosen rather than borrowing an existing commercial recording with its inherent post-production and the possible use of a metronome in the recording process.

A second methodological weak point of previous studies is that there has been little attempt to investigate the perception of 'good time'. In the 1950s Hirsh (1959) established that in order to differentiate successive tone onsets, a minimum of 2ms between tones is needed in non-musical contexts; later in a musical context, Gordon (1987) found that onset times could be within 20ms to maintain the perception of simultaneity. To the author's knowledge, only two studies have investigated the notion of groove perception in jazz performance (Busse, 2002) and in the performance of afro-cuban percussion music (Bilmes, 1993), showing that individuals are able to perceive the difference between derived performance model variations and mechanical performance models – different groove 'styles' – but the studies did not measure directly the quantities of timing discrepancies heard.

In a recent, thorough investigation of pulse-level perception, Butterfield (2010) investigated an individual's perception of small timing differences (10, 20 and 30ms) between the performed notes of drums and bass, by asking participants to say whether the drummer or bassist was temporally 'leading' and to choose which version contained more 'assertiveness'. His results showed that participants were not able to successfully discriminate between bass or drum leads nor determine which instrument was more assertive, which suggested to him that non-musicians are neither able to hear the effects of nor the actual asynchronies involved in musical contexts (Butterfield, 2010). However Butterfield's (2010) task demands were relatively complex for such small differences: rather than a simple discrimination task, subjects were required to both perceive differences and identify which of the two instruments was leading the other, which in turn involved deciding which instrument lead most of the time, as the percentage of time each instrument was actually leading ranged from 60.5% to 91%. Furthermore, it may be that these differences are too small to be utilised for decisions of temporal order, whereas judgments of the extent of temporal asynchrony would be a very different cognitive task. Finally, it may be that musical 'effects' manifest themselves in much simpler ways than 'assertiveness' – plausibly, one performance may simply sound more 'coordinated' or 'successful' than another.

In musical contexts, one can also calculate the quantity of difference that might be considered as a rhythmic possibility (dependant on the tempo of the musical piece – for example at 60bpm the shortest note played might be a triplet quaver with a duration of 110ms). As such, between this upper 'limit' and the lower limit of temporal perception (~20ms) lies the range of expressive nuance – a possible range in which musicians are playing 'good time' together. This study asked about where the perceptual cut-off is for the experience of music which is 'in time' or 'out of time', for inexperienced music listeners.

Two experiments were conducted (Experiments 1 and 2 described hereafter), in order to examine different aspects of perceived 'good time' in a jazz rhythm section. Experiment 1 investigated the types of inter-musician timing a listener perceives and prefers by presenting manipulated musical extracts from the same musical composition. Two dimensions of inter-musician timing were manipulated: the order of who played the note first and the temporal discrepancy between the two. The manipulations were natural asynchrony, perfect synchrony, systematic (fixed) asynchrony and inversely ordered asynchrony. Each of these conditions was designed to investigate the perception of naturally-occurring time differences between notes played by the two musicians (quantity) and temporal placement of notes played by the two musicians (order) in different combinations: systematic asynchrony removed quantity and retained order, inversely ordered asynchrony removed order but not quantity (a mirror opposite of the natural asynchrony condition) and perfect synchrony removed both quantity and order. Experiment 2 narrowed in on the precise quantity of temporal discrepancy between the drum and double bass notes that listeners associate with being 'in' and 'out of time'. This was done by systematically varying the quantity of inter-musician asynchrony present in extracts of the same musical composition, from none (perfect synchrony) to 120ms, by increments of 20ms (6 conditions). It would of course be a difficult task to hear and make a preference judgment for such small inter-musician timing differences, so in this study the task simply required participants to state *when* they heard a change in inter-musician timing.

2 Experiment 1: The Perception of Forms of Inter-musician Timing

2.1 Methods

2.1.1 Participants

96 undergraduate students from the Université Paris Ouest Nanterre La Défense participated in the study – 19 men and 77 women, with a mean age of 19.57 years (*sd*=1.51, [18-25]). On the basis of a self-administered questionnaire (presented in appendix xxx), it appeared that no participant had had formal musical training. Statistical tests showed that level of musical exposure had no significant effects on participants' responses.

2.1.2 Musical Stimuli

The musical stimuli were obtained using the audio tracks used in Study 2 presented in Chapter 6 (Protools tracks of the drum and double bass players for the composition "Ten" performed by the group Less Is More in the recording studio). Musical samples were chosen from the fourth and last version performed in the recording studio, as representative instances of 'good time'. Temporal markers were attributed to the onsets of each note played, for both the drum and double bass tracks, using the same methods and onset definition described in Chapter 6. Table 7 presents the timing of each individual note (drum and double bass) according to its position within the first 16 bars of the piece. As can be seen in the table, many more notes were produced by the drum strokes than by the double bass plucks. It was decided that only the notes on beats 1 and 3 of each bar (bolded in Table 7) would be manipulated in the unnatural timing samples as these were the notes that occurred together fairly consistently (performers often both hit a note on these downbeats but played notes *around* the offbeats 2 and 4).

Bar	Instrument	Note Onsets												
1	Drums	**8.718**	9.584	9.694	**10.019**	10.241	10.333							
	Bass	**8.720**			**10.050**									
2	Drums	**10.694**	11.187	11.291	11.512	11.621	**11.924**	12.104	12.232					
	Bass	**10.678**					**11.920**		12.261					
3	Drums	**12.551**	12.881	13.073	13.178	13.404	**13.514**	13.711	13.829	14.026				
	Bass	**12.599**					**13.509**				14.335			
4	Drums	**14.449**	14.750	14.932	15.041	15.244	**15.349**	15.557	15.669	15.855	15.960	16.191		
	Bass	**14.460**		14.945										
5	Drums	**16.284**	16.598	16.777	17.026	17.316	17.416	**17.521**	17.695					
	Bass	**16.261**						**17.546**		17.848				
6	Drums	**18.147**	18.466	18.681	18.774	19.029	19.106	**19.336**	19.418	19.603	19.716	19.958		
	Bass	**-**	18.479		18.789			**19.369**						
7	Drums	**20.016**	20.399	20.511	20.811	20.940		**21.583**						
	Bass	**-**	20.350		20.673		21.289	**21.595**						
8	Drums	**-**	22.208		22.844	**22.923**	23.058	23.353	23.487					
	Bass	**21.933**	22.472			**22.923**			23.418					
9	Drums	**23.656**	24.207	24.301	24.765	**25.263**	25.292	25.363	25.861	26.158	26.472	27.027	27.101	
	Bass	**23.888**				**25.002**	25.270	25.490	25.700					
10	Drums	**-**	27.232	27.341										
	Bass	**26.897**	27.218											
11	Drums	**27.540**	27.638	27.732	27.846	**28.050**	28.154	28.243	28.341	28.444	28.644	28.853	29.066	29.264
	Bass	**27.565**				**27.999**								
12	Drums	**29.357**	29.584	29.677	29.874	**30.303**	30.814	31.074	31.115					
	Bass	**29.408**				**30.322**	30.623							
13	Drums	**31.167**	31.637	31.691	32.105	**32.282**	32.607	32.897						
	Bass	**31.226**				**32.448**	32.729							
14	Drums	**33.002**	33.496	33.798	33.855	**33.920**		34.447	34.762					
	Bass	**33.082**				**33.970**	34.238	34.571						
15	Drums	**34.876**	35.365	**35.788**	35.968									
	Bass	**34.896**	35.349	**35.812**										
16	Drums	**36.575**	37.142	37.240	37.577	**37.786**	38.006	38.099	38.194	38.286	38.388			
	Bass	**36.621**			37.613	**37.873**								

Table 7: Note onset times in the double bass and drum tracks for the first 16 bars of one sample, with notes on beats 1 and 3 in bold.

Because the melody, harmony, and numerous other expressive features of their performance could also potentially influence listeners' perception of inter-musician timing, beginnings and endings of samples were defined in relation to the musical structure of the performed rendition. The rendition of "Ten" used for this experiment comprised 5 repetitions of the 32-bar harmonic theme. It was organised as follows: the guitarist played a solo with the drum and double bass accompanying him during 2 theme cycles (64 bars), the saxophone then entered playing the melody of the theme for one theme cycle (32 bars) with guitar, drums and double bass accompanying him, then soloed for 2 theme cycles with the same accompaniment (64 bars)(see Figure 7 in Chapter 6).

Five samples were chosen from each of these five theme cycles. All the samples consisted in a segment of 8 bars found in the same position of each cycle (Sample 1 = Bars 13-20; Sample 2 = Bars 45-52; Sample 3 = Bars 77-84; Sample 4 = Bars 109-116; Sample 5 = Bars 141-148)(Figure 15). In each sample there were 17 data points (8 bars x 2 notes per bar plus the first downbeat of the following bar). Each bar lasted around 2 seconds (a tempo of roughly 90bpm) and the duration of each sample was thus approximately 16s (Samples 1-5: 16.20s; 15.66s; 16.20s; 15.49s; 15.34s).

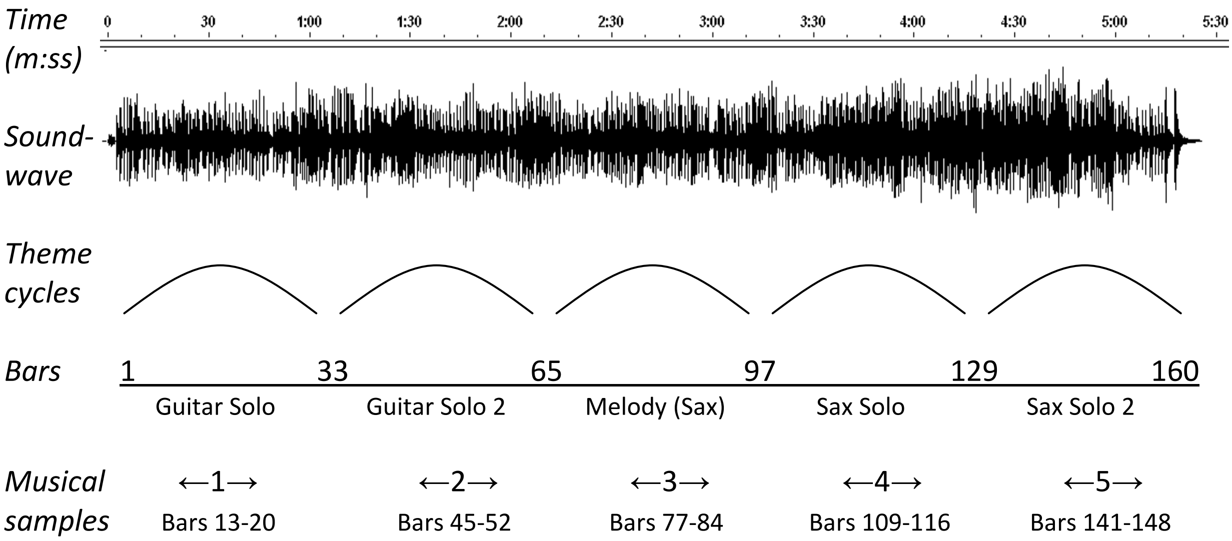
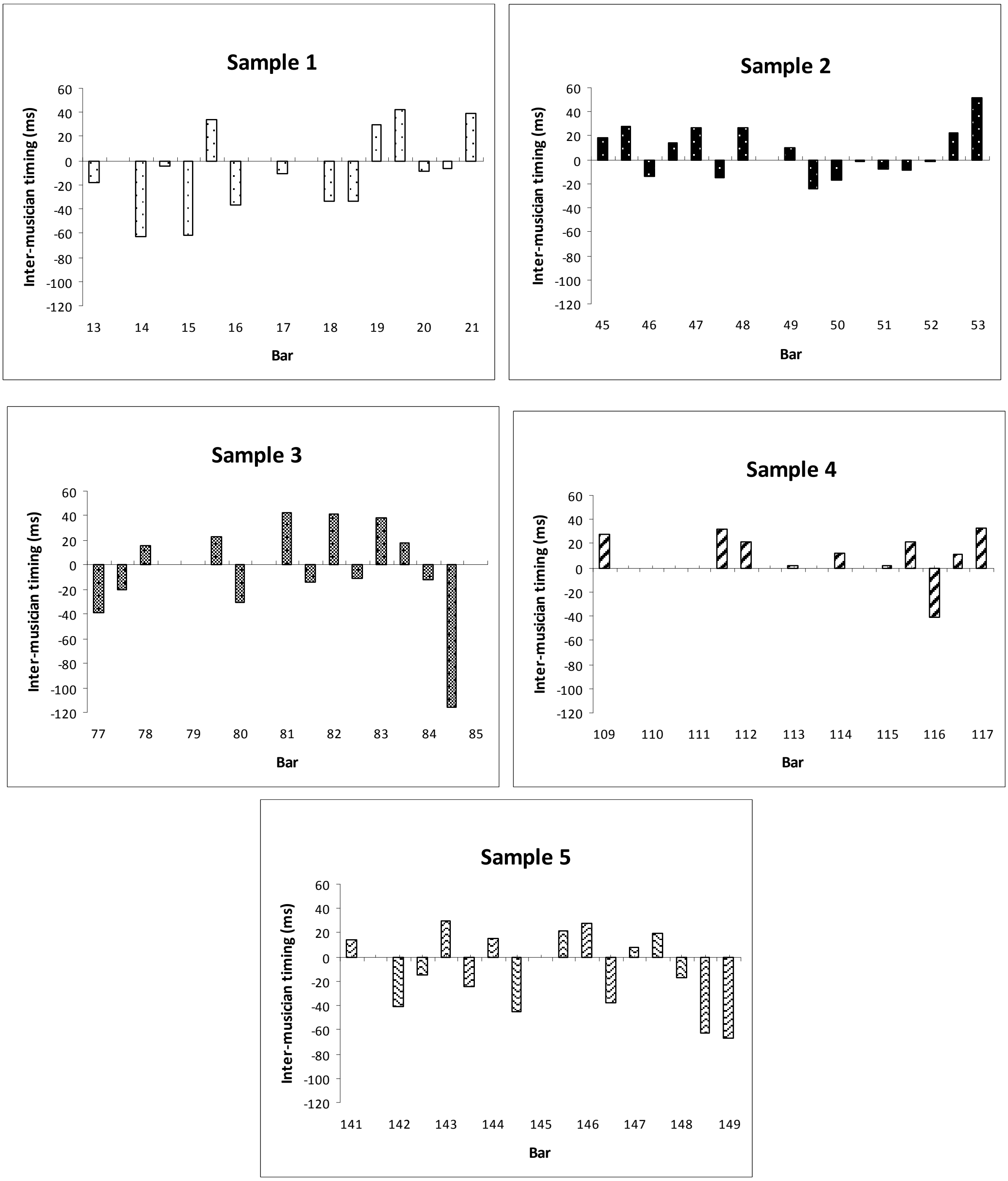


Figure 15: Figure showing the position of each sample used in the piece's development.

To check for similarity between samples, the inter-musician asynchronies of each of the five samples were graphed (Figures 16-20). Interestingly, notes were systematically uncodable (missing) on the downbeat just before the middle measure of the sample (beat 8). However, one of the samples was not included in the final cohort (Sample 4) because almost half of the data points were uncodable (7/17). The remaining four samples contained a similar distribution of inter-musician asynchrony, in terms of balance between the number of positive and negative shifts (i.e. one musicians being ahead of or behind the other) and in terms of quantifiable time gaps between the two musicians' audible notes.



Figures 16-20(Samples 1-5 respectively): Inter-musician timing performance in each of the five samples used.

The mean positive/negative inter-musician timing discrepancy was 5ms [*sd*=33.6ms] and the mean absolute inter-musician timing discrepancy was 27ms [*sd*=19.9ms]. It is notable that the only exceptional data point was the offbeat played before bar 85 (Sample 3) where the drummer played 116ms after the double bass player. These four samples were then tested statistically. An independent-samples ANOVA of the samples' absolute inter-musician asynchrony revealed no significant differences ($F(3)=1.71$, $p=0.175$) and a second ANOVA of the samples' inter-musician asynchrony keeping their signs (positive and negative) also revealed no significant differences ($F(3)=0.94$, $p=0.425$). (Means and standard deviations for each sample are presented in Table 8). Therefore these four 16-second samples, each occurring in a structurally similar position in the musical rendition can be considered to be equivalent in terms of inter-musician timing.

	Asynchrony (+/-)(s)		Absolute asynchrony (s)	
Sample	**Mean**	**SD**	**Mean**	**SD**
1	-0.010	0.035	0.030	0.019
2	0.007	0.021	0.018	0.013
3	-0.005	0.043	0.033	0.028
5	-0.012	0.033	0.030	0.018

Table 8: Mean and standard deviations of inter-musician asynchrony and absolute asynchrony in seconds, for the four samples used.

The following manipulations on the tracks were performed using the program *Ableton Live* (www.ableton.com/live), a music-making program for recording, programming and performing music. The program was used because it contains a particularly useful function for time-shifting individual notes with great precision, without disturbing any other characteristic of the note such as attack, pitch, or dynamics. All manipulations were performed on the double bass track and one of the drum tracks (the left overhead) only. The two individual tracks were imported to and exported from *Live* in .wav format, then the freeware editing program *Audacity* (http://audacity.sourceforge.net/) was used to save the two tracks together, creating samples for playback to the participants.

The four samples were then manipulated to reflect 4 synchrony-asynchrony conditions.

- For the first condition AN (natural asynchrony) no manipulations were performed on the tracks, so as to leave the naturally-occurring time differences (quantity) and temporal placement (order) in tact.

In the 3 other conditions, each of the drum (left overhead) and double bass tracks were manipulated by time-shifting the notes played on beats 1 and 3 by equal amounts.

- In the S condition (perfect synchrony) the tracks were aligned to leave no asynchrony between instruments: this was done by adding or subtracting half of the asynchrony between musicians to each track. For example, if the drummer played 116ms after the bass player's note, 58ms was added to the note onset of the double bass and 58ms was subtracted from the note onset of the drummer. It was decided that each track be manipulated by equal amounts in order not to bias one instrument in relation to another.

- In the AS condition (systematic or fixed asynchrony), the two tracks were first experimentally aligned (perfect synchrony), then temporally separate by a fixed quantity of 25ms (half each), keeping the original order. For example if the drummer played 116ms after the bass player's note, the double bass's note onset received +58ms - 12.5ms and the drummer's note onset received -58ms + 12.5ms, so that the drummer's note is played 25ms after the double bass. 25ms was chosen as the systematic fixed quantity because it was an approximation of the average (25.42ms) absolute asynchrony present between note onsets in each of the 5 original samples.

- To create the AI condition (inversely ordered asynchrony), the two tracks were temporally shifted by the same amount as the difference between the two in the opposite direction. In other words, the note onset times were swapped so that for example if the drummer originally played 116ms after the bass player's note, the drummer's note onset was attributed to the double bassist and vice versa, meaning that the drummer now plays 116ms *before* the bass player's note.

These manipulations are summarized in Table 9 below, and an example of the conditions is shown for Sample 1 in Table 10. Each manipulation was performed on every beat 1 and 3 of each of the four musical samples.

Stimulus Category		Type of Asynchrony	Manipulation	Position in Time
AN	Natural Asynchrony	irregular inherent asynchrony	no manipulation	DB<-- **-x**--> 0 <---- **+y** ---->Drum
S	Synchrony	no asynchrony	each asynchrony deleted, manipulation toward perfect synchrony between DB and Drums	---> DB 0 Drum <---
AS	Systematic Asynchrony	25ms* asynchrony imposed	each asynchrony deleted and 25ms added or subtracted keeping the original temporal order	DB<- **-12.5**-->0<- **+12.5**-->Drum
AI	Inversed Asynchrony	asynchrony order inversed	each temporal position for the DB replaced by the temporal position of the Drums and vice versa	Drum<-- **-x** -->0<----- **+y**----->DB

Table 9: The types of temporal manipulations performed on the double bass and drum tracks to constitute four experimental conditions. x,y = quantity of original asynchrony (ms). *25ms was chosen as it was the average absolute measured asynchrony. DB = Double Bass.

		Original Position (s)				*New Positions (s)*					
Condition:		**AN**				**S**		**AI**		**AS**	
Measure	**Beat**	**Bass**	**Drums**	**Difference**	**(ms)**	**Bass**	**Drums**	**Bass**	**Drums**	**Bass**	**Drums**
13	**1**	0.532	0.550	-0.018	**-18**	0.541	0.541	0.550	0.532	0.529	0.554
	3	-	1.547	-	-	-	-	-	-	-	-
14	**1**	2.505	2.568	-0.063	**-63**	2.537	2.537	2.568	2.505	2.524	2.549
	3	3.543	3.548	-0.005	**-5**	3.546	3.546	3.548	3.543	3.533	3.558
15	**1**	4.513	4.575	-0.062	**-62**	4.544	4.544	4.575	4.513	4.532	4.557
	3	5.614	5.58	0.034	**34**	5.597	5.597	5.580	5.614	5.610	5.585
16	**1**	6.607	6.644	-0.037	**-37**	6.626	6.626	6.644	6.607	6.613	6.638
	3	-	7.678	-	-	-	-	-	-	-	-
17	**1**	8.666	8.677	-0.011	**-11**	8.672	8.672	8.677	8.666	8.659	8.684
	3	9.629	-	-	-	-	-	-	-	-	-
18	**1**	10.62	10.654	-0.034	**-34**	10.637	10.637	10.654	10.620	10.625	10.650
	3	11.641	11.675	-0.034	**-34**	11.658	11.658	11.675	11.641	11.646	11.671
19	**1**	12.664	12.634	0.03	**30**	12.649	12.649	12.634	12.664	12.662	12.637
	3	13.698	13.656	0.042	**42**	13.677	13.677	13.656	13.698	13.690	13.665
20	**1**	14.678	14.687	-0.009	**-9**	14.683	14.683	14.687	14.678	14.670	14.695
	3	15.683	15.69	-0.007	**-7**	15.687	15.687	15.690	15.683	15.674	15.699
21	**1**	16.727	16.688	0.039	**39**	16.708	16.708	16.688	16.727	16.720	16.695
				Average	**-10**						

Table 10: Table showing the original positions in time (s) (AN= natural asynchrony) of the double bass and drum note onsets and the obtained temporal positions (s) for the 3 derived conditions S=synchrony, AI= inversed asynchrony, AS= systematic asynchrony, for Sample 1. When the difference is positive, the drummer played before/ahead of the double bassist and vice versa.

2.1.3 Testing Procedure

The subjects were tested in a university classroom with 3 rows of 6 chairs and tables evenly spaced such that each subject had their own table (a maximum of 18 people were tested at one time, and in such a way that individual participants could not see any other participant's responses. One stereo speaker (Yamaha Monitor Speaker MS202 II, 45 watts) with in-built pre-amp was placed 1metre to the side of a laptop PC at the front of the room. The farthest subject from the speakers was approximately 4 metres away. Instructions (in French) were read out to the participants explaining the experimental procedure. At the end of the procedure, participants completed a musical background questionnaire. The entire test lasted approximately 45minutes.

Participants heard a total of 16 musical extracts (4 samples x 4 conditions) presented in a randomized order. Each extract was heard twice in succession to ensure that participants' attention was focused on the task. Participants were asked to rate each of the 32 extracts according to the following 3 questions using a 5-point Likert scale. Because the predominant question in this study - 'being together in time'- was broad and refers to an intuitive experience rather than a well-defined and consensual notion, we chose to present participants with 3 different but related questions, expecting there to be a high level of redundancy between them.

- ⇨ Question 1) *Indicate how much you enjoy this version,*
- ⇨ Question 2) *Indicate the degree to which you believe this version is natural,*
- ⇨ Question 3) *Indicate the degree to which you believe the two musicians are playing 'together in time'.*

These questions were read aloud to the participants by the experimenter at the start of the testing period. For each question, the possible ratings were: not at all (1), not really (2), neutral/no opinion (3), a little (4), a lot (5)(see questionnaire format in appendix). Ratings were made using paper and pencil. A representation of one extract presented (condition AN) is shown below (Figure 21).

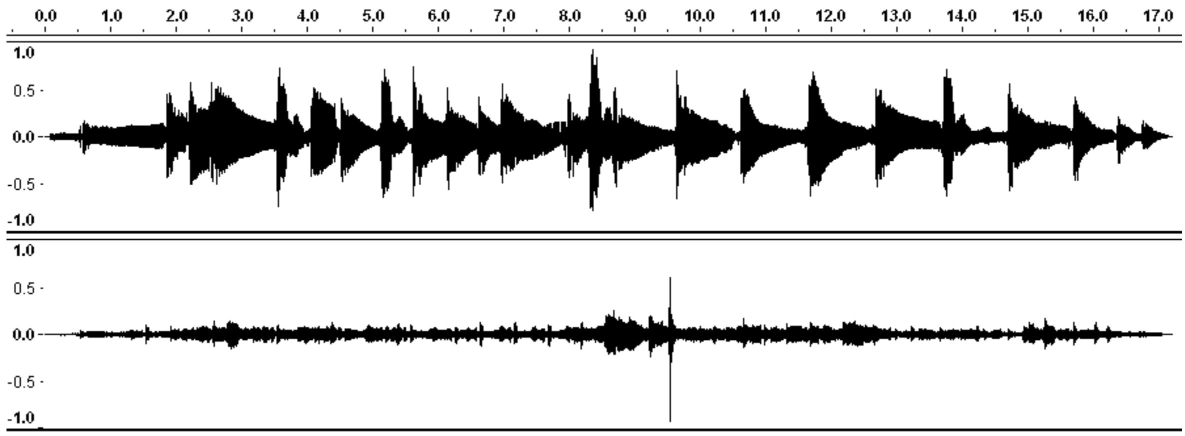


Figure 21: shows an extract of the stimuli used in the experiment: Sample one in the AN condition (no manipulation). The x-axis represents amplitude and the y-axis represents time (s). The double bass sonogram is on top and the drums sonogram is below.

2.1.4 Hypotheses

H1. Ratings should not be significantly different according to each of the questions.
H2. Ratings should be consistent with regard to each condition across the 4 samples.
H3. Ratings should always be highest for the natural asynchrony condition (AN), then for the inverse asynchrony condition (AI), then for the 2 other conditions.

2.2 Results

2.2.1 Descriptive Statistics

Mean ratings and standard deviations of each of the variables (Question, Sample, Condition) are shown in Tables 11-13 below.

Question	Mean	SD
1	2.934	1.162
2	3.043	1.081
3	3.101	1.193

Table 11: Mean and standard deviations of subjects' ratings
for each of the questions heard, all samples and conditions combined.

Sample	Mean	SD
1	3.210	1.158
2	3.039	1.127
3	2.860	1.101
5	2.995	1.180

Table 12: Mean and standard deviations of subjects' ratings
for each of the samples heard, all questions and conditions combined.

Condition	Mean	SD
AI	3.020	1.172
AN	3.005	1.177
AS	2.991	1.129
S	3.087	1.113

Table 13: Mean and standard deviations of subjects' ratings
for each of the conditions heard, all questions and samples combined.

When combining all other variables, there were no differences according to the 3 independent variables (question, sample and condition). This might have been expected due to the difficulty of the tasks. However, closer inspection involving the range and distribution of the responses may provide clearer insight into the way subjects heard and responded to each of the musical samples.

2.2 Investigating the 3 questions

As each of the questions were semantically different from each other and initial descriptive statistics showed an indication that subjects might indeed be responding differently depending on the question asked, the first analyses performed were to establish whether subjects responded differently to each of the three questions asked. A Kruskall-Wallis statistical analysis showed that there was a significant difference between the subjects' responses to the 3 different questions asked in the experiment ($K(2)=16.267$, $p<0.01$). Post-hoc comparisons (Mann-Whitney) were performed to establish which questions in particular were different from each other. These comparisons revealed that subjects answered Question 1 with significantly lower ratings than Question 2 ($Z= -2.613$, $p<0.001$) and answered Question 1 with significantly lower ratings than Question 3 ($Z= -3.894$, $p<0.001$), however there was only a small difference between the responses to Questions 2 and 3 (Z= -1.5470, p=0.122). In other words, subjects attributed higher liking ratings to Questions 2 and 3 than to Question 1. Because there were subtle differences between the way subjects answered each question, it was then decided to investigate the following variables Sample and Condition with respect to each question.

2.2.3 Performing analyses by musical sample

For each question, mean ratings and their standard deviations by sample were then examined and statistical tests were performed to examine the average ratings for each sample. The ratings for each of the three questions are represented graphically in Figure 22 below.

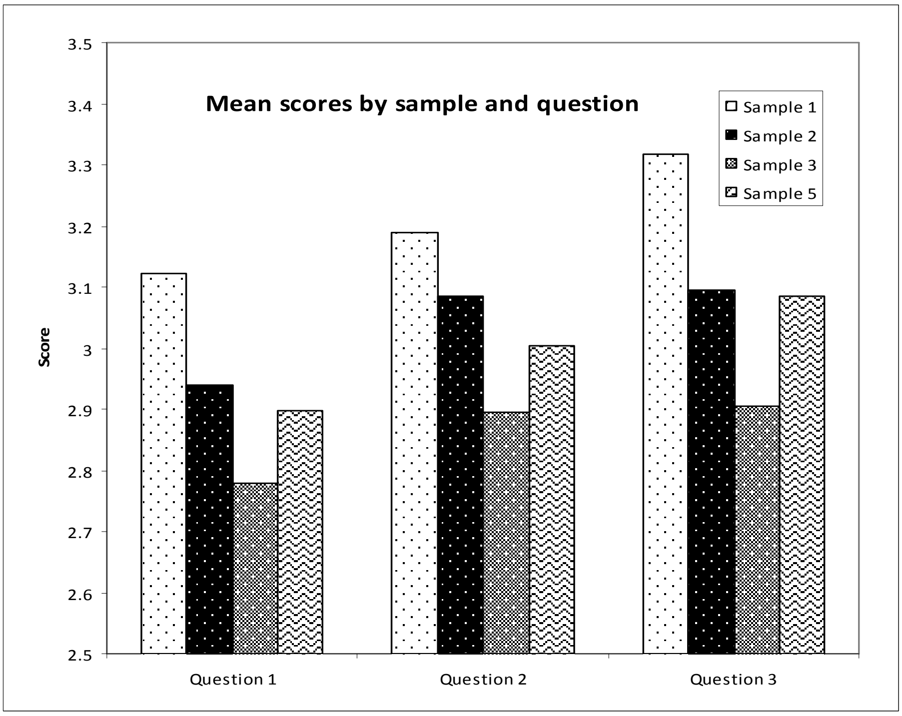


Figure 22: Mean ratings by sample and question.

Question 1: An initial Kruskall-Wallis test found that there was a significant difference between the way subjects rated the samples heard (K(3)=15.831, p<0.01). Two-tailed post-hoc (Mann-Whitney) comparisons between the means of samples 1 (3.121), 2 (2.939), 3 (2.779) and 5 (2.897) revealed where the principal differences lay. Sample 1 was rated significantly higher than Sample 2 (Z=2.134, p=0.033), it was rated significantly higher than Sample 3 (Z=3.994, p<0.01), and significantly higher than Sample 5 (Z=2.365, p=0.018). Sample 2 was not rated higher than Sample 3 though it approached significance (Z=1.826, p=0.068) and Sample 5 was not rated higher than Sample 3 (Z=1.477, p=0.140), nor was the difference between samples 2 and 5 significant (Z=0.308, p=0.758).

Question 2: An initial Kruskall-Wallis test found that there was a significant difference between the way subjects rated the samples heard ($K(3)$=13.833, p<0.01). Two-tailed post-hoc (Wilcoxon) comparisons between the means of samples 1 (3.189), 2 (3.084), 3 (2.895) and 4 (3.003) revealed where the principal differences lay. Sample 1 was rated significantly higher than Sample 3 (Z=3.593, p<0.001), and was rated significantly higher than Sample 5 (Z=2.144, p=0.032). Sample 2 was rated significantly higher than Sample 3 (Z=2.362, p=0.018). However, there were no statistical differences between the ratings of samples 1 and 2, 3 and 5. Samples 2 and 5 were again similar (Z=0.853, p=0.394).

Question 3: An initial Kruskall-Wallis test found that there was a significant difference between the way subjects rated the samples heard ($K(3)$=22.667, p<0.01). Two-tailed post-hoc (Wilcoxon) comparisons between the means of samples 1 (3.318), 2 (3.095), 3 (2.905) and 4 (3.084) revealed where the principal differences lay. Sample 1 was rated significantly higher than Sample 2 (Z=2.627, p<0.01), it was rated significantly higher than Sample 3 (Z=4.727, p<0.001), and significantly higher than Sample 5 (Z=2.561, p=0.010). Sample 2 was rated significantly higher than Sample 3 (Z=2.184, p=0.029) a was Sample 5 (Z=2.170, p=0.030). The only difference that was not statistically significant was the difference between Samples 2 and 5, for these two samples, the average ratings for the combined conditions were highly similar (Z=0.025, p=0.980).

In summary, there were a number of significant differences between subjects' ratings of each of the four musical samples. Sample 1 was rated systematically higher than the three other samples, and Sample 3 was rated systematically lower than the three other samples, but Samples 2 and 5 were rated roughly in between the other two and were highly similar to each other. These results cannot be accounted for by order of presentation effects, as this factor was randomized during experimentation.

2.2.4 Investigating types of inter-musician timing: analyses by condition.

For each of the questions, the mean ratings for each condition were then examined. Because the data involved non-normal, continuous, paired distributions, Friedman statistical analyses were used to compare conditions. For each question, mean ratings and their standard deviations by condition are represented graphically in Figure 23 below.

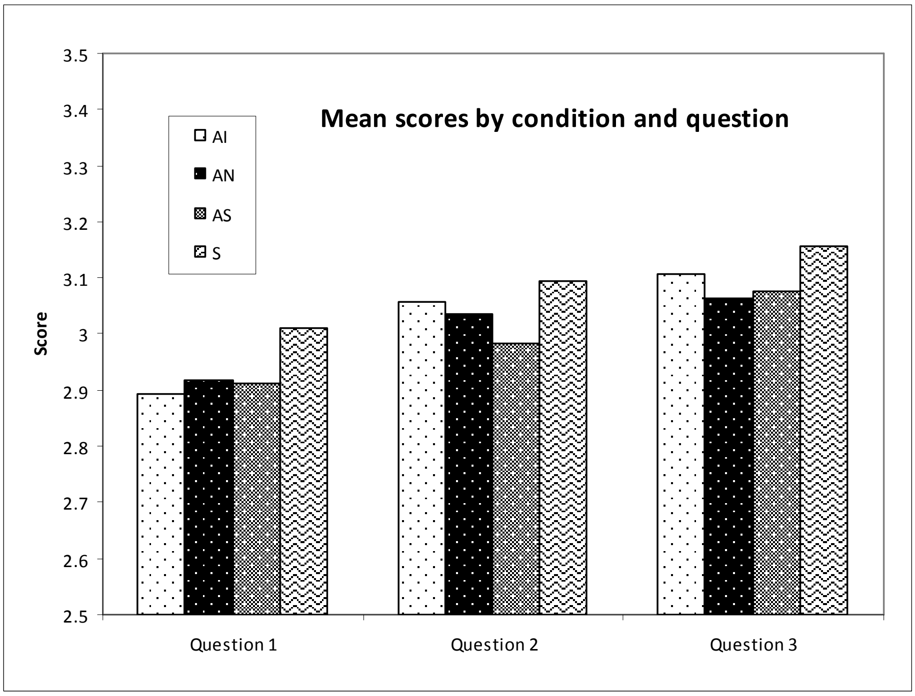


Figure 23: Mean ratings by condition and by question.

Question 1: For this question, the Friedman test did not reveal a significant difference between subjects' ratings for each of the four conditions ($Q(3)=4.210$, $p=0.240$), despite the synchronised version being rated with the highest mean (3.011 ratings).

Question 2: For this question, the Friedman test again revealed no significant differences between subjects' ratings ($Q(3)=2.155$, $p=0.541$), despite the synchronised version being rated with the highest mean (3.095 ratings).

Question 3: Similarly for this question, the Friedman test revealed no significant differences between subjects' ratings ($Q(3)=1.853$, $p=0.604$), despite the synchronised version being rated with the highest mean (3.155 ratings).

In summary, there were no differences between subjects' mean ratings for each of the four conditions of inter-musician timing heard. Subjects did not rate one condition over the others with significantly higher ratings. But because there were significant differences between subjects' ratings depending on each of the samples heard, in order to fully assess whether subjects were able to discern differences between each of the conditions, an analysis of the differences between conditions for each extract was then performed.

2.2.5 Analyses by condition and by sample

Because the data involved non-normal, continuous, paired distributions, the statistical analyses Friedman were used to compare conditions. For each of the questions and each of the samples, mean ratings per condition are represented graphically in Figures 24-26 below.

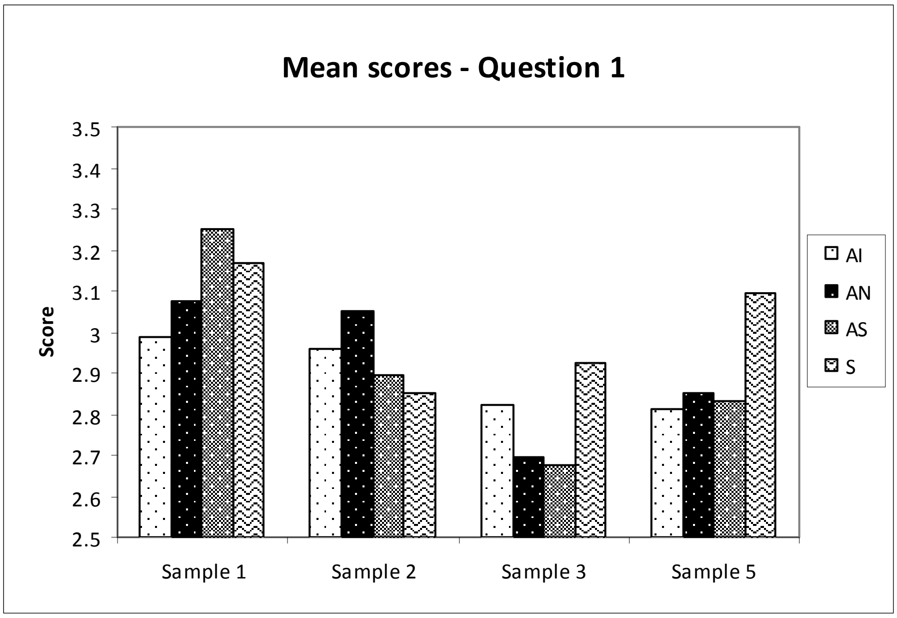


Figure 24: Mean ratings by condition and by sample, for Question 1.

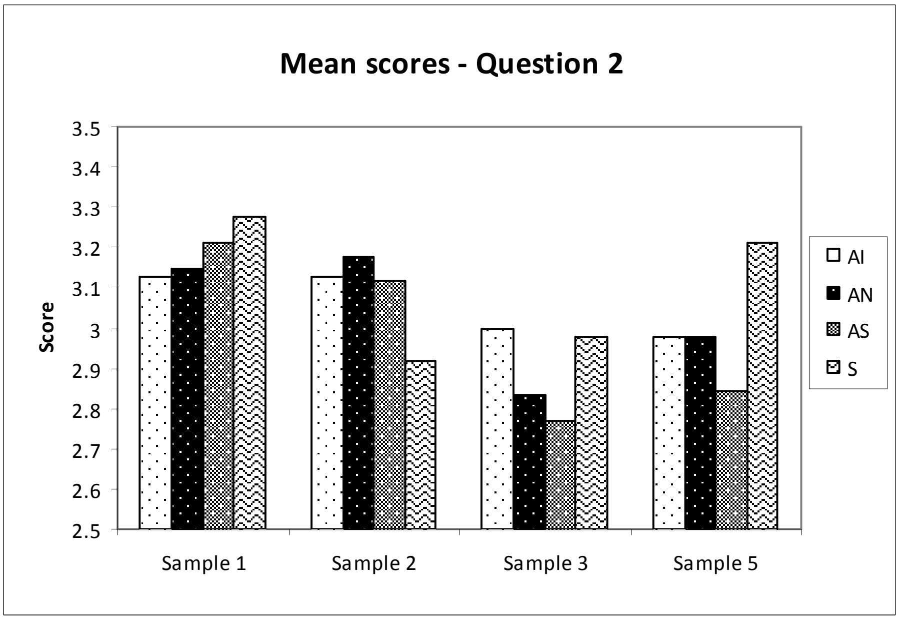


Figure 25: Mean ratings by condition and by sample, for Question 2.

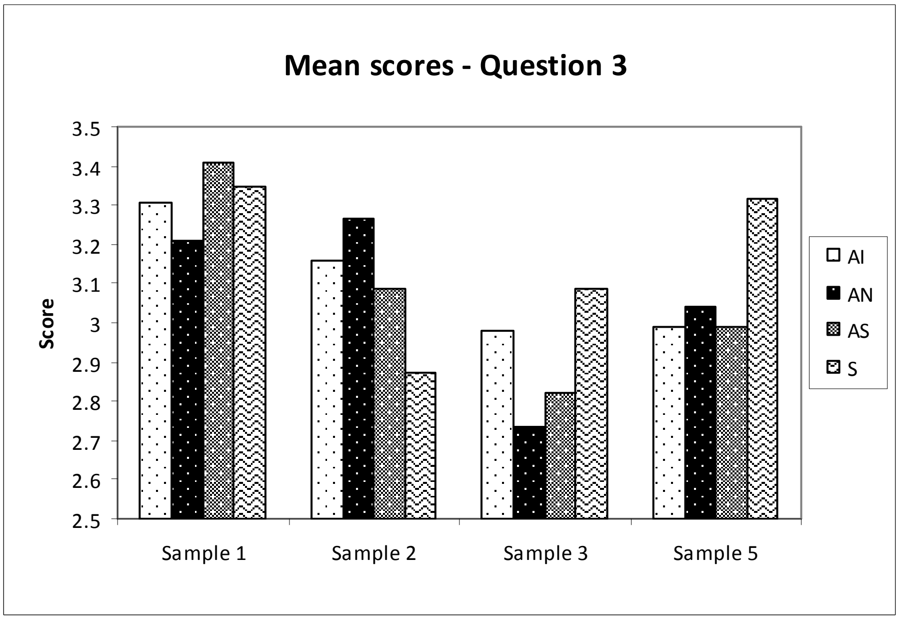


Figure 26: Mean ratings by condition and by sample, for Question 3.

Samples 1 and 2: For each of the three questions asked, Friedman statistical tests showed that subjects' ratings did not differ significantly between conditions.

Sample 3: For each question, Friedman statistical tests showed that the difference between conditions approached significance. For Question 1, the difference between subjects' ratings for each of the conditions approached significance ($Q(3)=6.350$, $p=0.096$). For Question 2, the difference between subjects' ratings for each of the conditions also approached significance ($Q(3)=5.926$, $p=0.115$), as did ratings for Question 3 ($Q(3)=6.432$, $p=0.092$).

Sample 5: A similar pattern of results was shown for Sample 5. For Question 1, the Friedman statistical test revealed that the difference between subjects' ratings for each of the conditions heard approached significance ($Q(3)=5.939$, $p=0.115$). For Question 2, the difference between subjects' ratings for each of the conditions also approached significance ($Q(3)=7.459$, $p=0.059$), as did ratings for Question 3 ($Q(3)=5.713$, $p=0.126$).

In summary, differences between subjects' ratings for each of the four conditions of inter-musician timing approached significance, for samples 3 and 5, and this result held for each of the questions asked.

2.2.6 Analyses of ranking

Because there were slight differences between the mean ratings for each of the conditions for samples 3 and 5, we wanted to investigate whether subjects were responding to one condition relative to another, in other words, whether there was a ranking effect on the conditions heard. Post-hoc (Wilcoxon) analyses were performed using both signed and signed rank statistical tests to establish whether there were any tendencies in the way subjects rated samples 3 and 5.

Sample 3: For Question 1, there were no significant differences between the size of the means of conditions AI and S, but there were small significant differences between conditions AN and S (a difference of 0.232 ratings – M=8.0, p=0.023), and between conditions AS and S (a difference of 0.253 ratings – M=7.5, p=0.063). For Question 2, there were no significant differences between the size of the means of different conditions. For Question 3, there were no significant differences between the size of the means of different conditions, excepting a small significant difference between conditions AN and S (a difference of 0.347 ratings – M=11.0, p<0.01).

Tests of signed ranks also revealed significant differences between the ordering of different conditions. For Question 1, Condition S was rated systematically higher than Condition AN (S=182.5, p=0.024) and it was rated systematically higher than Condition AS (S=222.0, p=0.067). For Question 2, there were no significant differences between the ratings of different conditions. For Question 3, Condition S was rated systematically higher than Condition AN (S=324.5, p<0.01), it was rated systematically higher than Condition AS (S=262, p=0.072) but not systematically higher than Condition AI. The distributions of the differences between subjects' ratings for each condition have been graphed in Figures 27-29 below.

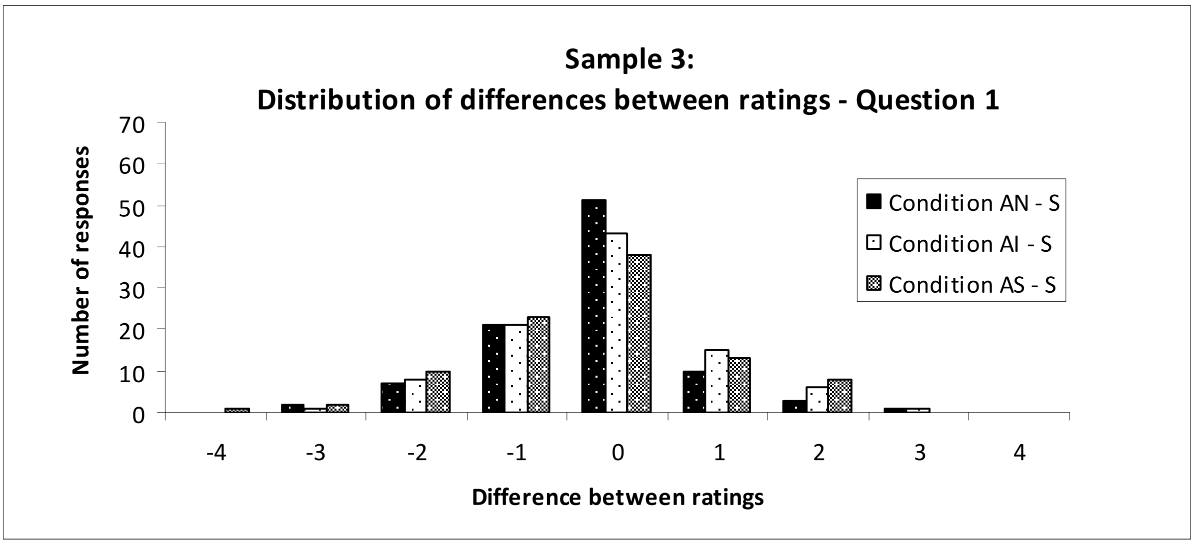


Figure 27: Distribution of differences between subjects' ratings for Sample 3, Question 1.

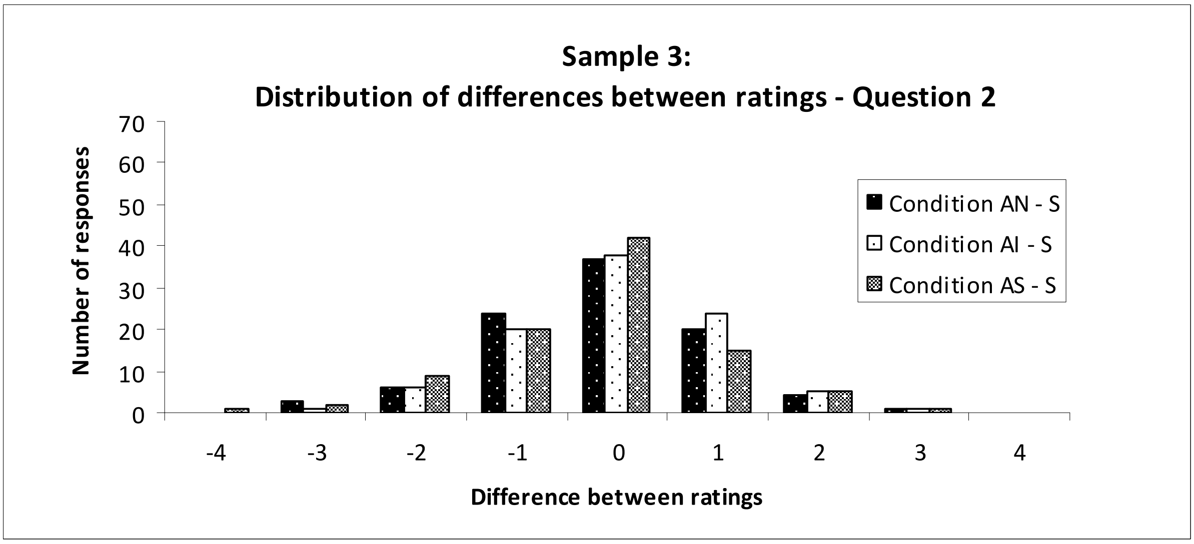


Figure 28: Distribution of differences between subjects' ratings for Sample 3, Question 2.

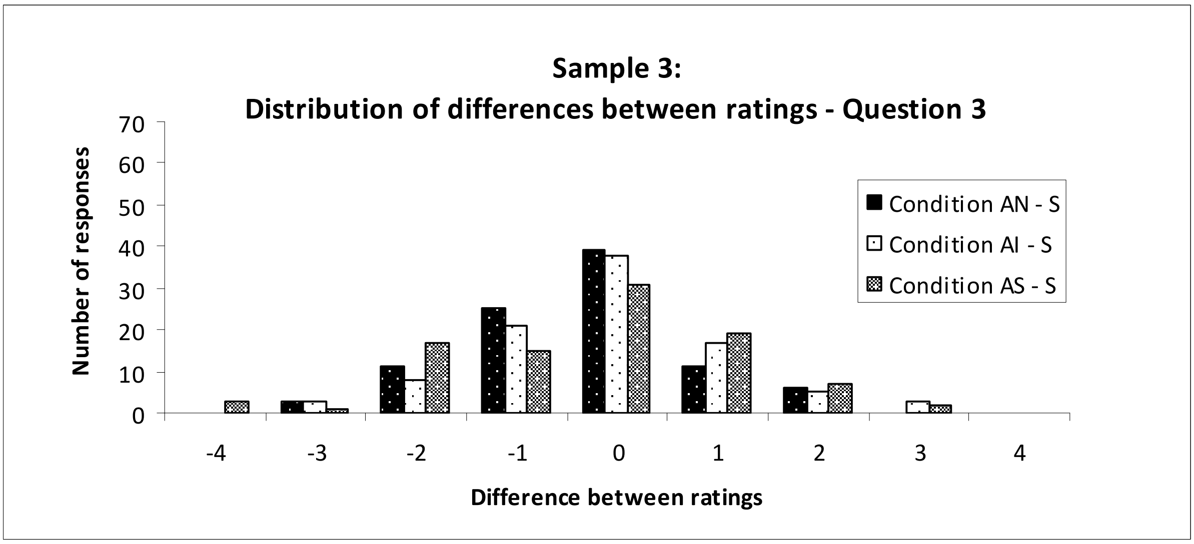


Figure 29: Distribution of differences between subjects' ratings for Sample 3, Question 3.

Figures 27-29, displaying the distribution of differences for Sample 3, show the way in which subjects tended to rank each of the conditions. For example, for Question 3 (Figure 29), there were roughly 40 subjects who rated Condition AN with the same rating as Condition S (a difference of 0, represented in black). There were also roughly 25 subjects who rated Condition AN with 1 rating less than Condition S (who - for example - rated Condition AN as '2' on the Likert scale and Condition S as '3' on the Likert scale). As can be seen, each of the distributions are slightly skewed to the left of 0, indicating a tendency for subjects to respond with higher ratings on Conditions S; these differences in ratings were significant in particular for Questions 1 and 3, and only between Condition S and Conditions AS and AN.

Sample 5: For Question 1, there were no significant differences between the size of the means of different conditions, excepting a small difference between conditions AS and S (a difference of 0.263 ratings – M=8.0, p<0.01). For Question 2, there were no significant differences again between the size of the means of different conditions, excepting a small difference between conditions AS and S (a difference of 0.368 ratings – M=10.5, p<0.01). Again, for Question 3, there were no significant differences between the size of the means of different conditions, excepting a small difference between the same conditions AS and S (a difference of 0.326 ratings – M=9.0, p=0.018).

However, tests of signed ranks revealed significant differences between the ordering of different conditions. For Question 1, Condition S was rated systematically higher than Condition AN (S=235.5, p=0.037), it was rated systematically higher than Condition AI (S=203.0, p=0.025) and systematically higher than Condition AS (S=147.5, p<0.01). For Question 2, Condition S was rated systematically higher than Condition AN (S=230.0, p=0.048), it was rated systematically higher than Condition AS (S=331.5, p<0.001), but not systematically higher than Condition AI. For Question 3, Condition S was rated systematically higher than Condition AN (S=273.0, p=0.059), it was rated systematically higher than Condition AI (S=262.5, p=0.016) and systematically higher than Condition AS (S=272.5, p<0.01). The distributions of the differences between subjects' ratings for each condition have been graphed in Figures 30-32 below.

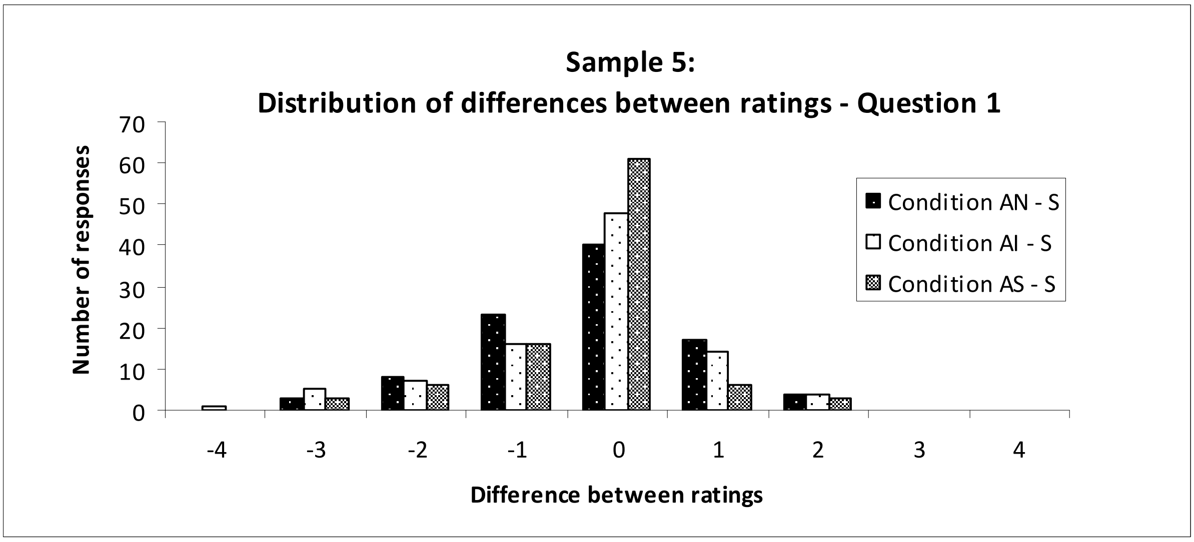


Figure 30: Distribution of differences between subjects' ratings for Sample 5, Question 1.

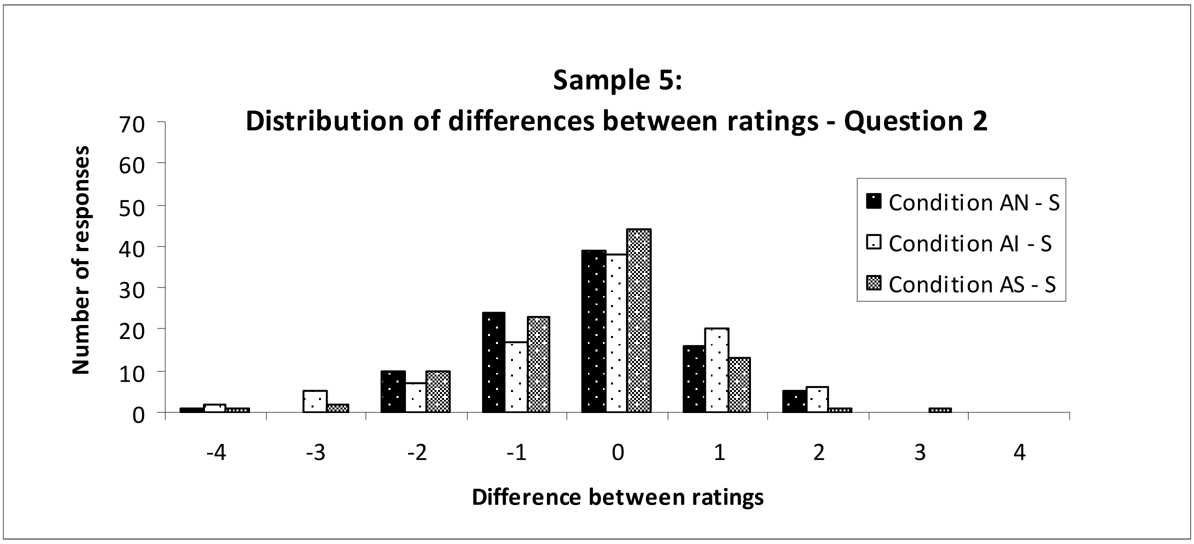


Figure 31: Distribution of differences between subjects' ratings for Sample 5, Question 2.

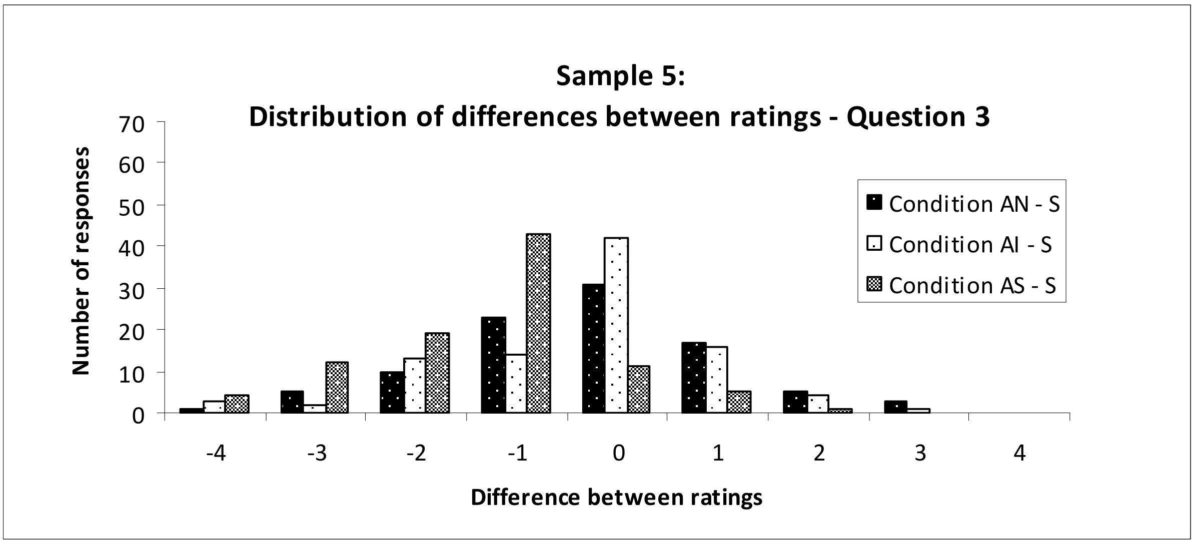


Figure 32: Distribution of differences between subjects' ratings for Sample 5, Question 3.

Figures 30-32 show the way in which subjects tended to rank each of the conditions. For example, for Question 3 (Figure 32), there were roughly 30 subjects who rated Condition AN with the same rating as Condition S (a difference of 0, represented in black). There were also roughly 43 subjects who rated Condition S with 1 rating higher than Condition AS (who - for example - rated Condition AS as '2' on the Likert scale and Condition S as '3' on the Likert scale). As can be seen, each of the distributions are highly skewed to the left of 0, indicating a tendency for subjects to respond with lower ratings on Conditions AN, AI and AS; this despite the greater concentration of 0 differences, which contributes to a null effect in the size of the differences.

In summary, for Sample 3, subjects tended to rate Condition S with, on average, between 0.25 and 0.35 ratings higher than Conditions AS and AN, but not Condition AI, and for Questions 1 and 3 only. Tests of signed ranks then confirmed that, for this sample, Condition S was ranked higher than Conditions AS and AN, for Questions 1 and 3. For Sample 5, subjects significantly tended to rate Condition S with, on average, between 0.25 and 0.35 ratings higher than the other conditions, for each of the three questions. Tests of signed ranks also revealed that, for this Sample, Condition S was ranked systematically higher than the other conditions, for each of the three questions. In general then, for Samples 3 and 5, subjects tended to rate the 'synchronised' condition as their preferred condition, they tended to rate this condition as being more natural than the others (Question 2)(although not for Sample 3), and they found that it represented the condition in which musicians were playing together in time (Question 3).

7.2.3 Discussion

Subjects attributed higher liking ratings to Questions 2 and 3 than to Question 1, leading to a rejection of H1. This may be in part attributable to a serial effect, as subjects were required to always answer these questions in the same order (1-3). This finding may also suggest that the questions were being treated as meaningfully different, however we might have expected that the preference rating (Question 1) would be higher than a rating of perceived synchrony (Question 3), being an easier task.

Sample 1 was clearly preferred by the subjects as it was rated higher than the others for each of the three questions asked. On the contrary, Sample 3 was clearly disliked by the subjects as it was rated systematically with lower ratings for each of the three questions asked. Something inherent in these musical samples singled them out with respect to the others, leading to the rejection of H2. Closer inspection of the musical material revealed the presence of what could be considered a musical 'error' in Sample 3 – the bassist played an audible note out of harmonic context – leading subjects to make preference judgements on this harmonic quality. Lower ratings were also given to Sample 3 for Question 3 which does not, in theory, relate to any quality other than the musicians' timing. It may be that subjects were indeed focusing on asynchrony, as there was, additional to the harmonic error, a large timing asynchrony in this sample (see Figures 16-20), leading them to perceive the third sample as that which was most 'out of time'.

There were no differences between subjects' mean ratings for each of the four conditions of inter-musician timing heard – subjects did not rate one condition over the others with significantly higher ratings when all samples were combined. However, for samples 3 and 5 in particular, differences between subjects' ratings for each of the four conditions of inter-musician timing approached significance. Ranked tests then confirmed that, for these samples, subjects tended to rate the synchronised condition with between 0.25 and 0.35 ratings greater than the other conditions. Importantly, subjects tended to rank the synchronised condition higher than all other conditions, for these two samples only. This result implies that musically-untrained subjects are able to hear and judge different forms of inter-musician timing in naturalistic jazz performances. Moreover, for specific samples, subjects prefer a musical performance in which all inter-musician timing has been removed, such that players are perfectly 'in time', as well as judging the performance to be more 'natural', and more 'in synchrony'. This finding was different from the expectation that subjects would prefer the condition with natural or original asynchrony, rejecting H3.

3 Experiment 2: Perceptual Thresholds for Inter-musician Timing

This experiment focuses on the precise quantity of inter-musician timing between a drum and double bass player that listeners perceive to represent being temporally 'in' and 'out of time'. This was done by systematically varying the quantity of inter-musician asynchrony present in each of 4 samples from 20ms (perceptual limit) to 120ms by increments of 20ms (6 conditions of inter-musician timing).

3.1 Methods

3.1.1 Participants

The subjects were the same undergraduate students as in Experiment 1 from the Université Paris Ouest Nanterre La Défense. There were 96 participants in total, 19 males and 77 females, with an average of 19.57 years of age (sd=1.51, eldest=25, youngest=18).

3.1.2 The musical stimuli

The musical samples were again obtained from the audio recordings presented in Chapter 6, using only the drum and double bass tracks from the fourth version of the composition "Ten" performed by the group Less Is More. Four, 16 second (8-bar) samples were obtained using the same methods described in Experiment 1. The following manipulations on the tracks were performed again using the programs *Ableton Live* (www.ableton.com/live) and *Audacity* (http://audacity.sourceforge.net/).

In order to create the 6 conditions, the drum and double bass tracks were first temporally aligned as if to create the 'synchrony' condition in Experiment 1. In order to create the condition in which 20ms of asynchrony was placed between the two musicians, 10ms were either added to or subtracted from each of the tracks depending on which instrument was initially temporally ahead of the other, so that the original order was kept. For example, if the drummer originally played 116ms after the bass player's note, the double bass's note onset received +58ms - 10ms and the drummer's note onset received -58ms + 10ms, so that the final result was "*double bass player <-- 20ms --> drummer*". To create the condition in which 40ms of asynchrony separated the musicians' notes, 20ms was added to or subtracted from each of the tracks, and so forth. An example of the six conditions is shown for Sample 1 in Table 14. Each manipulation was performed on every beat 1 and 3 of each of the four musical samples. There were four samples, each with six conditions, and samples were randomized to control for order.

		Original Position (s)			*New Positions (s)*											
Condition:					**20ms**		**40ms**		**60ms**		**80ms**		**100ms**		**120ms**	
Measure	**Beat**	**Bass**	**Drums**	**Diff. (ms)**	**Bass**	**Drums**	**Bass**	**Drums**	**Bass**	**Drums**	**Bass**	**Drums**	**Bass**	**Drums**	**Bass**	**Drums**
13	**1**	0.532	0.550	**-18**	0.531	0.551	0.521	0.561	0.511	0.571	0.501	0.581	0.491	0.591	0.481	0.601
	3	-	1.547	**-**	-	-	-	-	-	-	-	-	-	-	-	-
14	**1**	2.505	2.568	**-63**	2.527	2.547	2.517	2.557	2.507	2.567	2.497	2.577	2.487	2.587	2.477	2.597
	3	3.543	3.548	**-5**	3.536	3.556	3.526	3.566	3.516	3.576	3.506	3.586	3.496	3.596	3.486	3.606
15	**1**	4.513	4.575	**-62**	4.534	4.554	4.524	4.564	4.514	4.574	4.504	4.584	4.494	4.594	4.484	4.604
	3	5.614	5.58	**34**	5.607	5.587	5.617	5.577	5.627	5.567	5.637	5.557	5.647	5.547	5.657	5.537
16	**1**	6.607	6.644	**-37**	6.616	6.636	6.606	6.646	6.596	6.656	6.586	6.666	6.576	6.676	6.566	6.686
	3	-	7.678	**-**	-	-	-	-	-	-	-	-	-	-	-	-
17	**1**	8.666	8.677	**-11**	8.662	8.682	8.652	8.692	8.642	8.702	8.632	8.712	8.622	8.722	8.612	8.732
	3	9.629	-	**-**	-	-	-	-	-	-	-	-	-	-	-	-
18	**1**	10.62	10.654	**-34**	10.627	10.647	10.617	10.657	10.607	10.667	10.597	10.677	10.587	10.687	10.577	10.697
	3	11.641	11.675	**-34**	11.648	11.668	11.638	11.678	11.628	11.688	11.618	11.698	11.608	11.708	11.598	11.718
19	**1**	12.664	12.634	**30**	12.659	12.639	12.669	12.629	12.679	12.619	12.689	12.609	12.699	12.599	12.709	12.589
	3	13.698	13.656	**42**	13.687	13.667	13.697	13.657	13.707	13.647	13.717	13.637	13.727	13.627	13.737	13.617
20	**1**	14.678	14.687	**-9**	14.673	14.693	14.663	14.703	14.653	14.713	14.643	14.723	14.633	14.733	14.623	14.743
	3	15.683	15.69	**-7**	15.677	15.697	15.667	15.707	15.657	15.717	15.647	15.727	15.637	15.737	15.627	15.747
21	**1**	16.727	16.688	**39**	16.718	16.698	16.728	16.688	16.738	16.678	16.748	16.668	16.758	16.658	16.768	16.648

Table 14: Table showing the original positions in time (s) of the double bass and drum note onsets and the obtained temporal positions (s) of the 6 derived conditions with different amounts of inter-musician asynchrony, for Sample 1. When the difference is positive, the drummer played before/ahead of the double bassist and vice versa.

3.1.3 Procedure

Two groups were formed that either heard ascending or descending quantities of asynchrony. The ascending group first heard the condition with 20ms, then 40ms, 60ms, 80ms, 100ms and finally 120ms, with a few seconds of pause between conditions. They were then asked to respond to the question: *Indicate from which version you consider that the two musicians are not playing 'in time together', in other words, are no longer in phase or in synchrony with each other?* This was repeated for each of the four samples. The descending group first heard the condition with 120ms, then 100ms, 80ms, 60ms, 40ms and finally 20ms, with a few seconds of pause between conditions. They were then asked to respond to the question: *Indicate from which version do you consider that the two musicians are playing 'in time together', in other words, become in phase or in synchrony with each other?* This was repeated for each of the four samples. All participants heard a total of 24 extracts, each of which lasted around 16s (a total listening time of 6min24s not including response times).

With tasks that use ascending or descending sequences one would typically take the average 'the point of interest' in both series, in order to control for biases known as errors of habituation and expectation (Macmillan & Creelman, 2005). Errors of habituation would correspond to a subject becoming habituated to the experience and waiting longer before he responds to each question, such that the ascending question's response would be larger and the descending question's response smaller. Conversely, errors of expectation correspond to a subject responding early, such that the ascending question's response would be smaller and the descending question's response larger. In this study, however, a separate group of judges participated in each group (ascending, descending), because asking the same individual to listen to each piece of music twice would have introduced another bias - that of familiarity with the music. Musical context is a rich source of reference, and repeated exposure to each sample would likely influence the results. So it was not possible to eliminate each judge's biases entirely, but it was predicted that some judges would exhibit errors of habituation, and others errors of expectation, so that averaging across both conditions would likely control for bias to some extent.

3.1.4 Hypotheses

It was anticipated that the perceptual change in timing – the condition in which the musicians were considered to have become 'in' (or 'out of') time – would be greater than the smallest perceptual timing threshold (20ms) and smaller than the largest timing quantity performed (~120ms) from our own prior analyses of inter-musician timing (see Chapter 6).

H1. The greater the temporal discrepancy between musicians' notes, the greater the number of participants who considered them to be 'out of time'.
H2. The smaller the temporal discrepancy between musicians' notes, the greater the number of participants who considered them to be 'in time'.

We also anticipated that participants would be relatively stable in their choices between samples. Furthermore, it was expected that there would be no differences between participants' responses as a function of the order of presentation of the musical conditions. As some participants should exhibit errors of habituation, and others errors of expectation, averaging across subjects within a question should reveal the true (perceived) cut-off for being 'in' or 'out of' time. But between questions, as it seems unlikely that two musicians can be considered both 'in' and 'out of' time at once, we predicted that the cut-off for each would be the same. In other words, there should be a mean cut-off above which musicians are heard as no longer playing 'in time' together, and under which musicians are considered to be playing 'in time'.

3.2 Results

3.2.1 Performing analyses by musical sample

In order to establish whether it was possible to compare subjects' responses between questions by collapsing samples together, first it was necessary to check for homogeneity within the four samples used. Mean ratings are represented in Table 15 below. (Quantities of inter-musician timing correspond to differences between attack onsets of a bassist and drummer measured in milliseconds.)

	Mean Rating (ms)	
	Ascending	**Descending**
Sample 1	73.659	77.647
Sample 2	66.829	80.784
Sample 3	64.878	79.216
Sample 4	72.195	76.471

Table 15: Mean ratings (ms) of inter-musician timing for each of the four samples heard, for each of the ascending and descending groups.

For each group ascending and descending, factorial analyses of variance were performed, where the independent variable was the sample (1-4), and the dependent variable was the perceptual threshold for inter-musician timing (1-6 corresponding to each 20ms increment between 20ms and 120ms). No significant differences were found between the musical sample and subjects' perception of inter-musician timing. From here on, the four samples have been combined for further analyses.

3.2.2 Establishing the perceptual cut-off for being 'in' and 'out of' time.

Firstly, an ANOVA showed a highly significant effect of condition on the number of responses made ($F(5,18)=12{,}646$; $p=0{,}00002$). When does the change in perception of inter-musician timing occur for participants – the point at which musicians were considered to have become 'in' (or 'out of') time? The mean cut-off for all samples combined, and for both questions combined, was 74.46ms (*sd*=4.51ms). Amongst participants, however, there were inter-individual differences: the percentage of responses per category of inter-musician timing are shown in Figure 33 below.

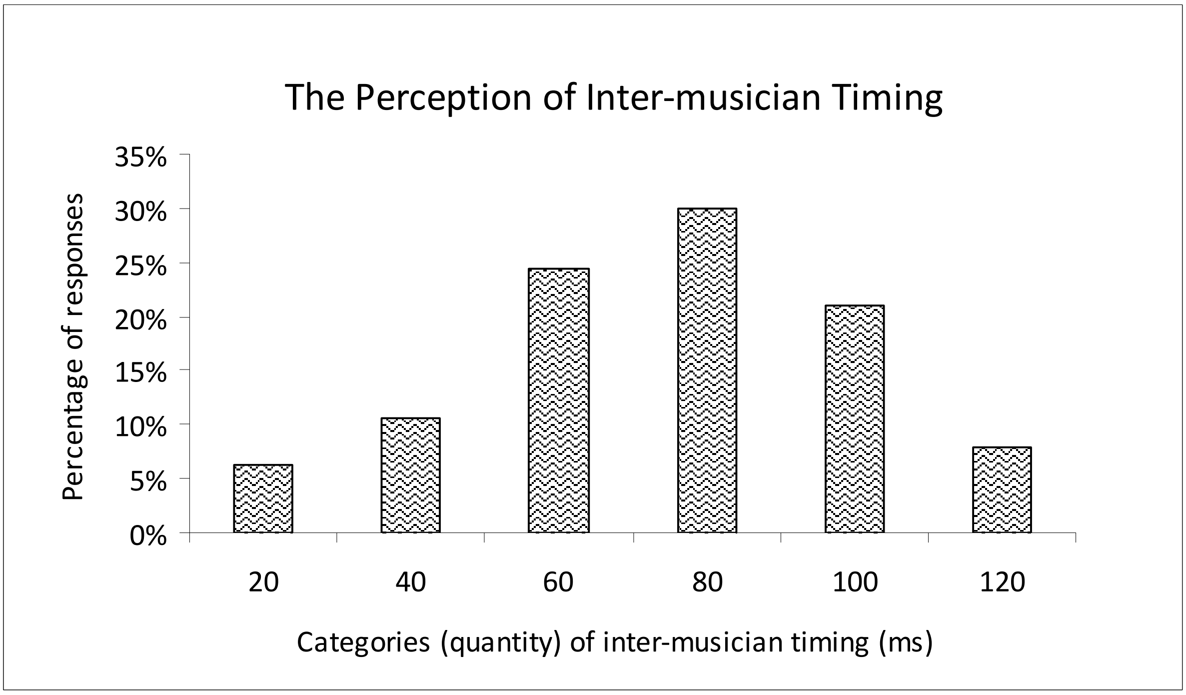


Figure 33: Figure showing the responses of the participants when asked to identify from which condition the musicians were either 'in time' or 'out of time', all samples and groups combined.

Over 50% of participants indicated that the cut-off point was at either 60ms or 80ms of inter-musician timing, and 75% of all participants indicated that this cut-off was between 60ms and 100ms. These descriptive statistics suggest a strong consensus between participants that the perceptual cut-off for being ‘in’ and ‘out of’ time lies somewhere between 60ms and 100ms. The data do not suggest that the greater the asynchrony performed between musicians, the more participants believe they are ‘out of’ time. Instead, the consensus might be described as a ‘temporal window of tolerance’, under which most participants agree that musicians are playing ‘in’ time, and above which they are no longer ‘in’ time together. In order to test whether this temporal window can be separated from the other (smaller and larger) responses, pair-wise comparisons (Tukey’s HSD) were performed between responses to each of the conditions. Significance levels are shown in Table 16 below, where significant p-values ($p<0.05$) are shown with an asterisk.

Response Correlations						
	20ms	**40ms**	**60ms**	**80ms**	**100ms**	**120ms**
20ms						
40ms	0,867					
60ms	0,002*	0,023*				
80ms	0,000*	0,001*	0,727			
100ms	0,015*	0,133	0,939	0,240		
120ms	0,998	0,980	0,005*	0,000*	0,035*	

Table 16: Pair-wise correlations between each of the 6 conditions of inter-musician timing (ms), with significant p-values ($p<0.05$) shown with an asterisk.

Two ‘temporal windows’ can be extrapolated statistically from this data. The first window can be considered as between 60ms and 80ms, and this range was significantly different from all other conditions (20ms, 40ms and 120ms). A second, larger window might be considered to include all responses between 60ms and 100ms – here, these responses were significantly different from all others excepting between 40ms and 100ms. In summary, additional to the point of absolute synchrony or cut-off between being ‘in’ and ‘out of’ time, there is clearly a range of tolerance to synchrony, where the majority of participants believe that musicians may be one or the other.

3.2.3 Analysis of the questions: Ascending versus Descending groups

Secondly, we wanted to establish the perceptual threshold at which participants perceive musicians to have become 'in' or 'out of' time, as a function of the order of presentation of the asynchronous conditions. This was to check whether errors of expectation and habituation were indeed being counterbalanced across subjects. Figure 34 illustrates the participants' responses below.

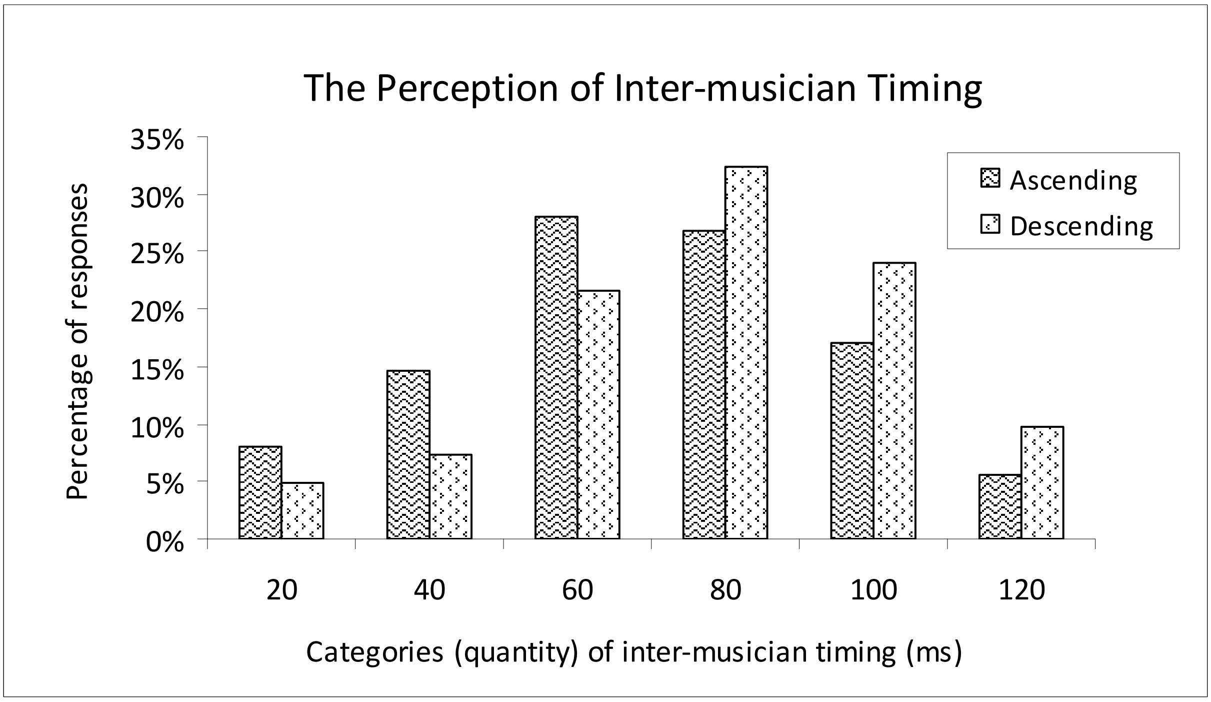


Figure 34: The responses of the participants when asked to identify from which condition were the musicians 'in time' or 'out of time', depending on the order of presentation of the conditions (ascending or descending).

As the order of presentation was not predicted to influence the way participants heard the musical samples, we expected no difference between participants' mean ratings between the ascending and the descending groups. A factorial analysis of variance was performed, where the independent variable was the group or order of presentation (ascending or descending), and the dependent variable was the perceptual threshold for inter-musician timing (conditions 20ms-120ms). The ANOVA, however, revealed a significant difference between mean ratings: the threshold for inter-musician timing perceived by the ascending group (m=69,39ms; σ=2,00ms) was significantly *inferior* to the threshold perceived by the descending group (m=78,53ms; σ=1,80ms) ($F(1,360)=11,55$, $p<0.01$)(Figure 35).

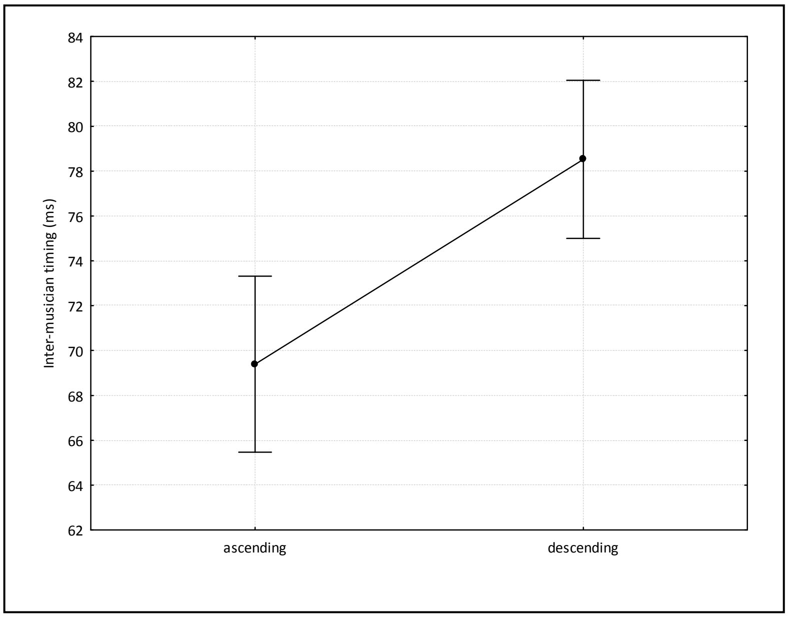


Figure 35: Figure showing mean inter-musician timing ratings (ms) per group, with 95% confidence intervals.

In other words, to the question "From when are the musicians no longer 'in' time?" (ascending group), subjects tended to respond with 60ms and above, and to the question "From when are the musicians 'in' time together?" (descending group), subjects tended to respond with 100ms and below.

This could imply that in both data sets (ascending and descending groups), the majority of subjects responded with a bias towards answering early - smaller asynchrony for the ascending group and larger asynchrony for the descending group - which are both representative of the expectation bias. This would be contrary to our hypotheses of seeing both biases counterbalanced in the results, but it is possible that this type of error predominated in each group. More likely, this result could instead require that we revise the notion of a perceptual cut-off between being 'in' and 'out of' time. When for example the subjects responded 80ms to the question "From when are they 'out of' time?", rather than meaning that musicians sound 'in' time under 80ms, it means that under 80ms the difference between 'in' time and 'out of' time' is not perceptible. This interpretation rather implies a 'temporal window of *ambiguity'*, in which listeners are not certain of whether musicians sound 'in' time or 'out of' time to them. Musicians may be considered as sounding both 'in' and 'out of' time, depending on the musical context of the performance.

3.3 Discussion

Across participants, there was a strong consensus as to an implicit understanding of the meaning of 'being in time'. Indeed, 75% of all participants agreed that the cut-off for perceiving the quality of being 'in' and 'out of' time lies somewhere between 60ms and 100ms. This consensus was initially described as a 'temporal window of tolerance', under which most participants agree that musicians are playing 'in' time, and above which they are no longer 'in' time together (in fact two temporal windows can be statistically justified).

[100ms+ **'out of'** time →

20ms *40ms* *60ms* *80ms* *100ms* *120ms*

← **'in'** time - 60ms]

However, the threshold for inter-musician timing perceived by the ascending group was significantly lower than the threshold perceived by the descending group. This result does not concur with the notion of a perceptual cut-off between being 'in' and 'out of' time, but supports instead the notion of a 'temporal window of *ambiguity*', in which listeners are not certain of whether musicians sound 'in' time or 'out of' time to them. Musicians may be considered as sounding both 'in' and 'out of' time, depending on the musical context of the performance, where the music has come from and where it is going.

[60ms **'out of'** time - - - →

20ms *40ms* *60ms* *80ms* *100ms* *120ms*

← - - - **'in'** time 100ms]

Another interpretation of these results is that the subjects tended to show an overall expectation bias, anticipating when they were supposed to respond. The experimental set-up implied that they knew at some point there would be a change, and that it would not be the last condition presented. For this reason there could have been more conditions included beyond 120ms, that is, beyond what is found in real life performance. A third possibility is that subjects were responding as a function of the question itself, logically the two questions are potentially different, as having the impression that two musicians are 'out of time' and 'in time' quite possibly carry very separate meanings.

There have been few studies investigating the perception of inter-musician timing. None, to the author's knowledge, have investigated the perception of being 'in' and 'out of' time, using manipulated quantities of inter-musician timing in live samples of jazz performance. The mean perceptual cut-off between being 'in' and 'out of' time was around 75ms, which lies in between the smallest perceptual timing threshold and the larger timing quantities that tend to be utilized in performance. This result is unique in that it does not tell us about the threshold or just-noticeable difference needed for perceiving inter-musician timing, instead it tells us of how musically untrained subjects experience music. It indicates that musically untrained subjects accept music with considerable timing gaps left between performers as still being music 'in' time.

8

Participatory Timing and Dynamic Form

1 Summary of Results

1.1 Study 1

In the first instance, intuitive ways of organising or structuring freely improvised performances can be reflected in musical episodes of interaction, which were approximately 9 minutes long, delimited by transitions that were conceptualised as *a pause or moment of rest between episodes of intensification.* Transitions between episodes were easily identified by both musicians who also reiterated several times the crucial importance of a musical set's architectural *shape.*

=> *Musicians spontaneously organise their interplay into episodes of intensification*

This study also provides some insight into the debate over the relative importance of flexibility or stability in successful musical interaction. In this study, the second day's improvisations were judged by MFM to be more relaxed, fluid and with a feeling of complicity between players. This day also corresponded to improvisations that were structured more 'formally', as the musicians spontaneously incorporated elements of three jazz standards into their improvisation. An additional finding was that experiences of good timing emerged only during sections of pulsed musical activity. These results together give some indication that the success of a performance from the point of view of the musicians performing (its creative energy and feel) depends on elements of stability, in timing and in shared musical content. This assumption can be linked to the requirement for a musical 'common ground' which is enabled through pulse and structure time.

=> *The experience of good time is enabled through pulse and shared knowledge.*

A third and key finding illustrated in this study was that the nature of good timing involves attentive listening and its display – musicians must feel that there is a dialogue between them conveyed through the mimicking and matching of musical ideas. This concept has been evoked many times in the informal reports of musicians themselves (Berliner, 1994; Monson, 1996). However, investigating the process by which good time emerges, by describing the musical and interpersonal events in each of three days of musical improvisations *as experienced by* one of the performing musicians, has provided a clearer, sound-based account of the phenomenon.
This link between good timing and dialogue implies sociability in the experience of good timing in jazz. The process of making music together is *seriously* fun, but musicians' intentional gestures and actions are not simply a means to an end: the affective experience does not result from the sound of their joint activities. Put simply, a Mexican wave at a rugby match is not particularly enthralling to watch on the television, is it affectively impressive only when participating in the coordinated activity itself. Affective, meaningful experience in "artful moving and thinking", comes from the making and sharing of activity, ultimately dependent on the "sympathy of companions" (Trevarthen, 2011, p. 1). This study has contributed, modestly, to demonstrating the way musicians' coordination is not only a means for getting in step, but also a collaborative endeavour that holds aesthetic value in itself.

=> *Good timing is a reflection of sociable human nature.*

1.2 Study 2

What distinguishes a temporally unsuccessful performance?

In this study, it was possible to quantitatively distinguish four versions of a song in terms of mean local tempo and local tempo curve development, mean inter-musician timing, but not mean activity. These results show, in the first instance, that it is possible to distinguish different versions of the same song at the pulse level, thereby documenting acoustic indices of good time.

=> *Quantitative evidence of temporal negotiation at the pulse level was shown.*

Version 3 was performed considerably faster than the three other versions, and moreover, the shape of the rejected version's local tempi development differed significantly from the other versions: in this version the musicians accelerated and arrived too quickly at their fastest local tempo. Musicians clearly define playing well together in terms of a specific dynamic trajectory of accelerations and decelerations in time, and finally 'hitting' the fastest tempo at a mutually negotiated moment in this musical piece.

=> *Good timing involves a mutually established local tempo trajectory that reflects or interprets the musical piece.*

Only Version 3 had timing that was significantly different from 0ms – in which the bassist was significantly more often ahead of the drummer. Despite the range of sound gaps left between musicians, in the other three versions the musicians took turns at performing ahead of and behind each other in equal amounts. This implies that it is not so much the quantities of inter-musician timing which directly influence musicians' impressions of good timing, but the relative balance of temporal leadership, reflecting fairness and respect in their temporal turn-taking.

=> *Good timing involves turn-taking at the pulse level.*

General tendencies in musical play

A key finding in this study is that interpersonal aspects of performance can be directly measured, such that we should not be contented explaining timing at the level of individual expression, but also at the level of social communication. An equal distribution of positive and negative inter-musician asynchrony measurements indicates the presence of negotiated pulse-level timing with respect to the co-constructed beat. Furthermore, despite the general tempo having been agreed upon before the performance, part of the musical process has been shown to involve dynamic temporal development in the course of musical play. Playing together in jazz clearly implies a continued awareness of the temporal development of each other's intentions, anticipating together where they would like their music to go.

=> *Interpersonal aspects of jazz performance are measurable*

Continued cycles or circular changes of local tempo, inter-musician timing, and double bass activity were found in each of the four versions, throughout the extent of musical play. With respect to inter-musician timing, not only do musicians leave considerable sound gaps between them, but they do so alternating with timing leadership: playing ahead of and behind the co-constructed beat while the other does the opposite. Monson (1996) and Keil (1994) have implied that style largely influences the inter-musician timing profile: depending on their style of interacting, musicians are either 'lay-back' or 'on-top' players. It may be that musicians prefer or tend to play in one way or another if we look at every note played, but on a large scale (and at structurally-important moments), this was not the case. Instead of each musician playing with his own style throughout the music, there was a real give and take or sharing of temporal leadership. This result may have been a reflection of the way these musicians were negotiating or working through their problems of good time in the course of musical play, but if it were the case, either the fourth, most temporally successful version should have shown fewer of these cycles, or the third rejected version should have shown more. Instead, they seem to represent inherent cycles of activity natural to performance.

=> *Cycles of activity are pervasive in jazz performance.*

Another central line of inquiry was based on whether the rhythm section's role is to maintain a strong, steady and isochronous pulse (providing stability), or to convey a malleable, subtly out-of-time pulse (conveying flexibility). This study has shown that the boundaries in which musical play with good timing can exist are more flexible than previously established. Significant changes in tempo – from 11 – 24% of the original speed – were observed, as well as considerable quantities and direction of inter-musician timing – over 100ms of asynchrony conveyed before and after each other's beat. With respect to tempo, several authors have insisted or implied that for a beat to be 'useful', tempo must remain fairly consistent throughout a performance (Jungers, Palmer & Speer, 2002), and that in jazz music this is particularly the case (Collier & Collier, 1994; Iyer, 2002). We might like to think that jazz performance is less forgiving in terms of local tempo variation than in classical Western music's instances of *rubati*, but the results described here cannot support this assumption. Concerning inter-musician timing, several scholars have measured timing with respect to what they assume to be a tightly-knit pulsative beat performed by the rhythm section players (e.g. Ellis, 1991), but again, the results described here indicate otherwise: rhythm section interplay also reveals serious asynchrony.

1.3 Study 3

Experiment 1: The sound of natural versus perfect synchrony

There was a significant effect of sample as ratings were different for each sample heard: Sample 1 was rated systematically higher than the others and Sample 3 was rated with systematically lower scores. In other words, samples were not treated as equivalent, implying that something inherent in these musical samples singled them out with respect to the others. One of the contributing factors may have been the large inter-musician asynchrony of 116ms or the musical 'error' both observed in Sample 3, which could have been excluded from analyses for this reason. Interestingly, Sample 3 was the sample which subjects globally liked the least in comparison to the others. However, it is unclear why Sample 5 has also stood out in the analyses.

One possible lead could be the narrative aspect of musical development, as samples were sequential in relation to the actual song's performance (Sample 1 was near the beginning and Sample 5 near the end). It may be that subjects expect or prefer types of inter-musician timing with respect to where in the performance they occurred – performed timing certainly differs with respect to musical events and structures. In Study 2, upon closer inspection of Figure 13, there was some indication that inter-musician timing was tighter according to the narrative progression of the song, with several instances of loose timing in the first sections, but fewer near the end. However, this result is only speculative, and larger samples of performances would be needed to confirm this notion.

When all other variables were combined, subjects did not prefer one condition of inter-musician timing to another, but performing analyses on each sample revealed that for samples 3 and 5 only, subjects showed a preference for the synchronous condition over the others. Analyses of ranking showed that despite the conditions being very closely rated, subjects ranked the S condition systematically higher than the others. In summary, for Samples 3 and 5, subjects rated the 'synchronised' condition as their preferred condition, they rated this condition as being more natural than the others (Question 2)(although not for Sample 3), and they found that it represented the condition in which musicians were playing together in time (Question 3).

A key implication for this experiment was that musically-untrained subjects are able to hear and judge different forms of inter-musician timing in naturalistic jazz performances. With respect to Questions 1 and 2, this result implies that listeners prefer music with perfect temporal synchrony between players over natural, imperfect synchrony and other forms of inter-musician timing. But uniquely with respect to Question 3, this result rather implies that subjects were in fact *correctly* identifying the condition in which the musicians were more synchronised or technically, mathematically 'in time'. If subjects were answering each question similarly, then both implications may be correct.

=> *There is some indication that subjects are able to identify and prefer the synchronous condition over others.*

Experiment 2: The sound of being 'in' and 'out of' time

The first notable finding was the mean change in perceived timing – the point at which musicians were considered to have become 'in' (or 'out of') time – which was found to be approximately 75ms. This result lies neatly in between the previously-established capacity of perceiving 2 separate tones (20ms - Hirsch, 1959) and the 'limit' for musically considering a note to be the same as another's (this depends on tempo, but at 65bpm the shortest note played might be a triplet quaver with a duration of 120ms).

However, a more appropriate representation of subjects' responses is that 50% of participants indicated that the cut-off point was at either 60ms or 80ms, and 75% of all participants indicated that this cut-off was between 60ms and 100ms. These descriptive statistics suggest a strong consensus for a perceptual cut-off between being 'in' and 'out of' time. We describe this consensus as a *temporal window of tolerance*. This result is unique in that it does not tell us about the threshold or just-noticeable difference needed for perceiving inter-musician timing, instead it tells us of how musically untrained subjects experience music.

=> *Musically untrained subjects accept music with considerable timing gaps left between performers as still being music 'in' time.*

Analysis of the questions between ascending and descending groups revealed a significant effect of order of presentation of conditions. Furthermore, the threshold for inter-musician timing perceived by the ascending group was significantly inferior to the threshold perceived by the descending group. In other words, subjects tended to perceive musicians to be 'out of' time with 60ms or more of asynchrony between them, and to be 'in' time with 100ms or less of asynchrony between them. This result has meant that the notion of a perceptual cut-off between being 'in' and 'out of' time should be revised – rather, we propose that there is a *temporal window of ambiguity*, in which listeners are not certain of whether musicians sound 'in' time or 'out of' time. That is, our results suggest that there is some overlap between notions of being 'in' and 'out of time' such that a given inter-musician gap might be tolerated in one musical context but not in another.

This study presents with mixed results then with respect to the initial research question asked. In addition, several weaknesses are revealed as it is one of the first studies of its kind: investigating the perception of being 'in' and 'out of' time using live samples of jazz performance. Future studies will need to include a greater number of samples, always from the same musical composition, same position in the musical structure, same instrumentation and same players, but making sure to choose only those samples for which the original quantities of inter-musician timing – means, medians and standard deviations – are highly similar. Despite these shortcomings, these experiments have shown that it is possible to test a musically untrained individual's perception of inter-musician timing in live musical contexts.

2 General Discussion

The primary objective of this thesis was to further understand the experience of *being in time together*. One of the specific aims was to further understand whether the experience involves temporal stability, flexibility, or a combination of both.

A combination of both stability and flexibility appears necessary for good timing in live musical collaboration. In Study 1, musicians spontaneously organised their interplay into episodes of intensification, within which the experience of good time appeared at times but not at others. Furthermore, the experience of good time was enabled through pulse and shared knowledge.

In Study 2, cycles of each of the three variables support the idea that variability is needed rather than strictly isochronous local tempo or rigidly synchronous timing. However, the presence of large timing discrepancies, together with cycles of being more or less synchronous in equal or balanced amounts, implies that both may be needed: variability in the size of the timing gaps left between them, and a steady balance of temporal leadership. With respect to local tempo, we have shown that greater variability exists in the change of local tempi than previously established, but clear stability exists in the shape of the local tempo trajectory. Thirdly, the constant changes in amount of musical activity attest to variability and dynamic participation and yet the averages across versions are relatively stable.

In Study 3, the debate between the relative merits of flexibility and stability in performance at the pulse level was taken up from the perspective of a music listener. Experiment 1 showed that listeners 'naïve' to the jazz idiom are able to identify and prefer the synchronous condition over others in two of the musical samples, implying that individuals are able to hear subtle temporal differences in jazz rhythm section performance. This result encourages a stable interpretation of successful jazz timing – implying that tighter timing between musicians is more appreciable at least from the perspective of naïve listeners. However the results from Experiment 2 imply that subjects are not as sensitive to the temporal nuances actually being performed as experienced musicians, requiring on average 75ms in order to perceive a change. Yet listeners demonstrated a very strong consensus about this range of acceptable inter-musician timing, which again implies that a balance between stability and flexibility in musical play.

A second aim of this thesis was to establish at which levels of musical timing flexibility and stability apply. Is the experience of good time dependent on moment-to-moment timing – the level of pulse – or is it rather dependent on longer spans of over-arching temporal shaping – the level of narrative? These notions will be explored in the following sections.

2.1 Good time is out of time

Studies of the biological basis of timing have demonstrated that the ability to entrain to a periodic pulse is in fact one of the most automatic and impulsive of human activities and has been demonstrated extensively under a variety of complex conditions (Merker, 2009; Repp, 2005). But when individuals are free to produce their own rhythmic pulse they consistently demonstrate spontaneous variation (Madison, 1998; 2001). If, as this work has shown, 'flexible entrainment' is ubiquitous and enjoyable, why is this so, if we are capable of entraining to others with near-perfect synchrony? In jazz practices, Keil and Feld's (1994) work has provided great insight into the processes by which two musicians make music together with groove, encouraging a focus on processual aspects of music-making which have long been put to one side in traditional musicological analysis. Moreover, their approach has brought us down 'into the groove' by showing us that process is observable at a pulse level. In live performance, temporal differences between where one musician places his notes, where a co-musician places his notes and where the score determines the note to be played occur often, are sizeable and are meaningful (Keil & Feld, 1994; Prögler, 1995).

The results from the studies reported here support this notion. In Study 2, considerable asynchrony was found throughout performance – inter-musician timing differences of between -150ms and 134ms – indicating significant variability in the size and direction of the sound gaps performed by the rhythm section players. Importantly, it would appear that in live musical contexts, much of the performance's feeling is created through processes at this pulse level. In the first instance, the results described in this thesis are in agreement with Keil's (1987) contention, that "Music, to be personally involving and socially valuable, must be 'out of time'" (p. 275).

In improvised performance musicians are at once seeking to be individually expressive and to coordinate their behaviours with the other musicians around them. Playing music in time at the pulse level implies both getting in step – tuning in and entraining one's musical behaviour to that of another musician – and conveying musical expression through variation. The extent and combination of deviations are in theory innumerable, therefore the skill is in choosing which of them to use and when, and how far to take them. "With the wrong choices, a performance becomes mechanical, 'just a collection of notes', or conversely, affected and kitsch" (Ball, 2010b, p. 304). People are quick to notice when a performance is too emotional, as when we have the impression that emotions are 'cheaply' exaggerated, which indicates that there are limits or boundaries within which expression can be conveyed convincingly or successfully.

Boundaries of participation are clearly relevant to this work as good time has been shown to encompass lower and upper perceptual and productive limits at the pulse level. In the perceptual realm, the third study detailed in this thesis has demonstrated that listeners intuitively allow a *temporal window of ambiguity,* with a strong consensus for a limit above which musicians appear to be 'out of' time, and a limit under which musicians appear to be 'in' time together. In the realm of music production, the second study revealed that playing neither too fast nor too slow for a given musical piece enabled successful temporal expression, further evidence of a boundary of temporal limits.

This is not, however, simply a question of deviations which are reflective of 'getting in time', in which case musicians would use a metronome in all of their performances. Madison and Merker (2002) argue that "a margin of tolerance for such deviations is necessary for synchronisation to occur" (p. 201). However, the theory of communicative musicality has proposed that we are *biologically programmed* to seek out and share multi-modal experiences with others in synchrony, but with controlled, meaningful variation (Malloch & Trevarthen, 2009). As a result, the principles of music are grounded in physical movement itself: "even the most difficult invention and learning of music is obedient in its making to impulses felt in the body" (Schögler & Trevarthen, 2007). As such, timing are the result of a natural inclination to shape expressive sounds into meaningful lines that encourage anticipation and support coordination (Gratier, 2008).

Because of this, I would reformulate Madison and Merker's notion and propose that a margin of tolerance for deviations is necessary in order for musicians to have the space in which to feel that they are in time with each other. Along these lines, Turner and Pöppel (1983) propose that sets of rules exist which influence and increase the potential range of human behaviour, rather than restricting it. "Variation does not occur *despite* the rules but *because* of them." (Turner & Pöppel, 1983, p. 290, italics in original). However, turning this proposition on its head, it would appear that boundaries of participation are in place *because of* the human motivation to be expressive through variation and to share meaning with others at this level.

When boundaries of participation are pushed, such as when a drummer performs his notes too often ahead of the bassist, conscious awareness emerges. This can be compared to a conversational setting in which one partner takes his turn a little too often by pushing his way into the dialogue – at some point the pushing becomes obvious and the focus changes to the flow of conversation itself rather than the ideas that were being exchanged. This idea is supported by Csikszentmihalyi's (1997) notion of flow: if an individual becomes too aware of the processes involved in the interaction then one can 'loose the flow' which immediately translates into conscious awareness.

My findings illustrate the way musicians co-construct a shared time-space in which they may 'play' or 'converse' together. There are clear temporal boundaries within which musical expression occurs, but they are *necessarily* flexible in order to suit moment-to-moment communicative needs. Furthermore, the mean inter-musician timing values examined in Study 2 demonstrate that musicians take turns at leading and following, being either ahead of or behind the co-constructed beat, and always with equality. This result lends itself to the interpretation that a musical, natural 'ideal' is not to be perfectly temporally aligned at all times with another, but to take turns at being temporally ahead of and behind the other, implying a sense of temporal 'fairness'.

2.2 Participatory Timing

Musicians' negotiations then reflect the natural tendency to perform with spontaneous variation at the pulse level, but they also reflect an intersubjective synchronisation or mutual 'tuning-in' referred to in social phenomenology (Schutz, 1951). A key finding from Study 2 was an equal distribution of positive and negative inter-musician timing measurements, indicating the presence of negotiated pulse-level timing with respect to the co-constructed beat. Interpersonal aspects of performance clearly come through in measurable form, such that we should not be contented explaining timing at the level of individual expression, but also at the level of social communication. and very social, interpersonal and cultural dynamical conventions of how to play well together in time.

Monson (1996) hints at this aspect of performance when she refers to the 'interactional layers' between both soloist and rhythm section and amongst rhythm section members. Keil (1987) however was one of the instigators of a theory including both expressive timing and discrepancies which appear *between* the instruments – and music-makers – in an ensemble. Keil focused on the way musicians use expressive timing at the sub-syntactical level, different from syncopations and offbeat rhythms, to create the impulse that makes music 'come alive'. Keil's (1987) dubbed 'participatory discrepancies' or PDs are said to be typically on the order of less than 50ms, which either generate an experience of rhythmic drive ('push') or of relaxation ('layback'). Referencing this theory, Butterfield (2006), however, argues for a consideration of syntactical pattern as being additionally responsible for creating 'engendered feeling', or more specifically, that we consider the interaction between PDs *and* syntactical pattern. According to Butterfield (2006), it is the strategic manipulation of anacrusis, a technique generated at the level of syntax through the use of micro-temporal subtleties, that drives an effective groove.

However, in light of the results presented here, it is more appropriate to search for good time and musical meaning by considering PDs in the sociable contexts in which they emerge. Essentially, I believe there is a need to develop Keil's (1994) theory of participatory discrepancies, re-focusing on the participatory aspects of micro-level timing. Because of a musician's skill at performing precisely in synchrony if so desired, a considerable portion of the inter-musician timing variance must be related to a social negotiation of the pulse by two thinking musical partners. This essentially means that, in addition to their manner of playing with a certain rhythmic style, and in addition to colouring the musical piece with expressive timing, the musicians are using the placement of their attacks to 'say something' to the other musicians around them.

This additional source of timing that is a reflection of social, interpersonal interaction, might be called *participatory timing* – conceptually different from *expressive timing* which can be conveyed through individual performance alone. The term participatory timing has been chosen to align with current research which refers extensively to the term expressive timing, but to importantly add the participative dimension to its core, in keeping with recent work rejecting methodologically individualistic approaches to social cognition (De Jaegher, 2006; Moran, 2007). Furthermore, I share Keil's (1987) contention that "we need more of this participatory consciousness if we are to get back into ecological synchrony with ourselves and with the natural world" (p. 276).

In addition, in improvisatory musical genres we find "the rhythmic patterning of intentions and impulses laid bare, displaying the motives that construct the seeking of consciousness and the desire to communicate" (Schögler, 2002, p. 14). Our communicative musicality – a variable, biologically-motivated pulse – requires that we take this concept of participatory timing even further. The participatory timing present in musical play, in addition to being a reflection of the negotiation of individual expression, can be a reflection of the negotiation of individual, instinctive motives for expression. When two musicians end their improvisations together in perfect synchrony, anticipating the unraveling of the last sequence of notes to within milliseconds of each other's performance, both a cultural and a natural awareness of the organisation of sound in time must be involved (Gratier, 2008). In Study 2, when the local tempo was changed willfully, this constitutes a collective agreement to change the rate of shared inner time.

That the power of improvised music is said to come from a *shared* sense of time resonates with Michel Imberty's (2005) writings: pleasure in music comes both from alternating between repetition and variation and from the simple fact of being together and playing with a shared sense of time. Musicians not only push and pull at the beat because they have learnt to do so through an understanding of the culturally-constructed musical conventions of playing with style. Musicians do this because negotiating at the pulse level is the means by which they inherently express meaning to others and share meaning with them in time. Participatory timing is based upon the very foundations of social communication.

However, this scale of timing is not necessarily present at a conscious level. Timescales of human movement show that periods below roughly 200ms imply times of action and response below conscious discrimination, but they may be considered a 'pre-conscious' level of representation

(Osbourne, 2009; Trevarthen, 2009). Rather, Stern (2000) suggests that the modulation of our biologically-determined pulses can communicate powerful acoustic messages about the "energy, state of metabolism and vitality affects" of the player (p. 53). In this respect, musical expression involves a direct line of transfer from its emotional core to its pulse-level, variable effects.

Why is 'flexible entrainment' ubiquitous and enjoyable? Animals such as crickets and frogs also appear to entrain to the pulse of one another, ending up in synchronised choruses of sound (Merker et al., 2009). But the pleasure for these beings in doing so might rest there. For humans, not long after we synchronise our motives and become tuned-in to one another, we naturally demonstrate *participatory timing*, by attempting to push and pull at each other's pulse, taking turns, teasing and being teased, and playing with the beat. This is the essence of companionship in musical play (Trevarthen, 2001). Turn-taking involves more than culturally-prescribed morals of how to play nicely in time: it is a biological, emotionally-driven human instinct to share meaning with others, in time.

2.3 Extended Narratives – Telling Stories

One fundamental aspect of our communicative musicality is that we are not only negotiating timing at the pulse level, we are also working together to build expressive phrases, narratives, and extended narratives in our stories over time. This aspect has also come to the foreground in the studies presented here. The intuitive episodes of interplay exposed in Study 1, in addition to the local tempo variation present in the studio performances of Study 2, both reflect the way in which musicians negotiate the overarching narrative of their performance as it unfolds before them. With reference to Study 2, in all real-time music-making performers tend to speed up as they play (Drake, 1968), but they also must constantly negotiate how to speed up together. This development must be at once derived from the culture and idiom of jazz performance, and resultant of a natural propensity to shape expressive sounds into meaningful motifs that 'afford' anticipation and support coordination (Gratier, 2008). Such large-scale temporal development might be linked to what LaRue refers to as *growth* (1970), and Monson as *intensification* (1996, p. 139), said to be the most important criteria when defending the aesthetic and artistic success of particular musical works.

In Study 2, the over-arching forms or shapes of dynamic narrative expression, as represented by local tempo curves, were distinct. This patterning echoes the work of Michel Imberty (1981; 1991; 2005), who has often emphasised consideration for the extended narrative structure of all creative endeavours in time, with its characteristic tension and resolution. It is precisely the organising principles of repetition and variation which contribute to the 'dynamic drive' of music, putting it into motion (Imberty, 1997, 2005). Others have stressed that the 'shaping of time' is perhaps the most important element in all expressive music performance (Epstein, 1995). Clynes' (1992) time forms or sentic forms are described as nature's generators and communicators of emotion, and can be seen in various forms of collaborative musical improvisation. For Clynes (1992), these basic dynamic forms, or message units, are evident in each gesture, tone of voice, musical phrase and dance step, and importantly "it is the character of the form, not the particular output modality that determines its emotional meaning." (Clynes, 1992, p. 2).

The shape of the progression of local tempi clearly highlight the way in which musicians are working together to convey the mutually-established narrative intent of this musical story to us. Because this quality is so crucial in playing good time together, it explains why the musicians spontaneously and wholeheartedly agreed that the third version, who's music *intensifies* unlike the others, just didn't work. There may be an ideal, co-constructed narrative shape specific to the musical piece musicians are performing. This finding fits in with a description of a prototypical musical form in the EDM scene, involving characteristic intros, buildups or builds, cores, breakdowns, and outros. But it is also interesting to note that a form which is *too obvious* is not necessarily liked either. Dramatically climactic builds, using extensive snare drum rolls and crescendo, are a hallmark of trance music, but the "obviousness of these characteristics is a major point of criticism for those who do not like the genre" (Butler, 2006, p. 223). For others, such obvious buildups can be "cheesy": DJ Shiva describes how such tracks are "all about just bringing you up and smashing you down, and not making you think anywhere along the way" (DJ Shiva, in Butler, 2006, p. 227).

At the narrative level, musical performance can also illustrate the notion of give and take. The musical descriptions explored in Study 1 revealed that an experience of good time comes and goes throughout performance – musicians are not always playing good time together. In reference to creating music with groove, Levitin (2006) implicitly agrees about the importance of dynamic expression rather than a constant, 'all-or-none' experience. As Langer (1953) originally proposed herself, Levitin (2006) suggests that musical expression should essentially imitate the dynamics of human emotion:

"Real conversations between people, real pleas of forgiveness, expressions of anger, courtship, storytelling, planning and parenting don't occur at the precise clips of a machine. To the extent that music is reflecting the dynamics of our emotional lives, and our interpersonal interaction, it needs to swell and contract, to speed up and slow down, to pause and reflect" (p. 172).

2.4 Working it Out Together – Negotiating pulse and form together in time

The studies presented in this thesis have provided support for combining both stability and flexibility in musicians' temporal expression. Importantly, it has been shown here that good time involves sharing or negotiation at different musical levels: listening to and sharing melodic and harmonic ideas, listening to and negotiating the structure of the musical work, listening to and negotiating with the pulse of other musicians. Musicians are very much in control of their timing at both small and larger scales of production: from pulse-level expression to large-scale narrative forms, musicians are working together to make their music meaningful and representative of their collective expressive ideals. We are perhaps forgetting that musicians are capable of and enjoy 'playing around' with time on many different levels at once, and that they enjoy this, lulling us into a sense of security with the stability of one factor while teasing and pulling at another. This multi-level expression indicates that musicians have in their minds a representation of their performances in terms of both small-scale and large-scale processes at once.

Meyer's early writings (1956) suggest that in Western classical musical genres, resolutions must be anticipated and gratifications deferred, and that only upon the ultimate arrival of these resolutions does the composition gain a sense of coherence. Keil (1994), however, places the functionality of 'groove-based' musical genres including jazz in opposition to this: instead, jazz's guiding principle of 'vital drive' is said to be present throughout the extent of a performance, and that gratification is not deferred but immediate. Hodson (2007) agrees that without the obligation to create any 'long-range sense of closure', jazz performances emphasise spontaneous gestures rather than incorporating them into a coherent whole.

This approach appears to be pervasive when scholars deal with jazz performance. Iyer and colleagues have proposed (1997) that African-derived musical structures are "less 'deeply' organized on a large scale (in the sense of the 'depth' of a recursive tree) than Western tonal structures, but are frequently 'deeper' […] on a small timescale" (Iyer, Bilmes, Wright & Wessel, 1997, p. 1). For these scholars, African-derived or groove-based musics place greater importance on small time-scale events including cyclicality, reference to a shared body of knowledge, and composite percussive patterns. This is certainly the case by comparison with Western classical genres, or our treatment of them in musical analysis in the last century. However, they also claim that less importance is placed on the grouping of such events into progressively larger sections, instead musical works of these genres often have several sections that are repeated in a cyclical manner for 'arbitrary' lengths of time (Iyer et al., 1997). Furthermore, transitions between sections are said to be cued in an "improvisatory fashion, quite possibly without a preordained large-scale temporal structure or a linear notion of time" (Iyer et al., 1997, p. 2).

The results presented in this thesis do not support this notion: neither timing at a moment-to-moment basis nor over-arching temporal expression appears to have priority over the other. I would argue, rather, that both are interdependent, and that this is precisely how musicians 'say something' to fellow musicians and to their audiences, because this is how people instinctively dialogue with others in all communicative contexts, negotiating pulse-level timing and building projected futures.

As an example of their interdependency, at the narrative level musicians demonstrate the notion of give and take, as the experience of good time by necessity comes and goes throughout performance. However, this does not mean that time literally breaks down, as musicians do not drop their instruments and stop playing altogether. Rather, an overall structure remains with them while they work together again at rebuilding good time at the level of pulse. This is what MFM refers to with his intuitive comment that at some point the two musicians are 'vague' and 'not perfectly together in time', but that they manage overall to 'catch up'. When participative timing breaks down, narrative structure compensates and holds everything together. By the same token, it is possible for pulse to compensate for narrative, when for example an ensemble is performing together, with good time, without 'going anywhere' – perhaps two rhythm section members waiting for the saxophonist to change his reed before coming in to play a tune's introduction.

When two or more musicians are in time together they are in time both with the underlying rhythms of their music and its meaningful expression. Their movements and sounds become one single, unified activity which creates something more than the sum of its constituent parts. Lee and Schögler (2009) refer to being 'in the groove' as a "feeling of fitting perfectly in a way that is unique to the actions of the movement and dependent on being with someone else" (p. 99). In this way, musicians are not only separate individuals doing their own separate things, they are acting collectively, and the result is "both functional and beautiful" (Lee & Schögler, 2009, p. 99).

2.5 Good Time: An enabling process and an enjoyable experience

A concluding thought to this general discussion is that successful temporal coordination – playing good time together – can be considered as both 1) necessary for and *enabling* of the structuring of their musical interactions and 2) fun, experiential and *enjoyable*, i.e. the result of a process that has been successfully worked-through together. This idea stems from Gratier's (2008) notion that groove involves both pragmatics and aesthetics (respectively): it is both a means of keeping in step, and the process of 'grooving together' conveys emotion and holds aesthetic value in and of itself (Gratier, 2008). Importantly, the two are intimately related: saying something or successfully communicating musical ideas and dialoguing around them, leads to an experience of good timing – a musical conversation gone well; and conversely, the process of establishing good time is one the *objectives* of meaningful expression.

"It's about feeling like time itself is pleasurable"
(Don Byron 1989, cited in Monson, 1996, p. 68).

2.6 Clinical applications

The study of our engagement with time goes well beyond the scope of this thesis to explore a diverse range of disciplines including music therapy and dispute resolution. In the latter field, scholars are investigating the ways in which individuals might change their perspectives focusing on the narratives of discourse as a way of encouraging the resolution process (Riskin, 2004). Indeed, negotiators are often advised to recognise the power of and differences between their own and others' perceptions of time, particularly in intercultural settings (McDuff, 2006).

The most direct consequence of this work in a clinical domain is to build on the notion of being together in time, which is in and of itself a pleasurable activity for young and old alike. I believe it is crucial today that we encourage society to consider music as a collaborative, enjoyable activity that is a natural extension of our motivation to be in time with others and create meaning through our time spent together. This is a particularly relevant issue in a society which increasingly facilitates access to simplified, digital and distancing media forms of musical expression, and separates the musical few from the un-musical masses.

> *"One does not need to have any formal knowledge of music – nor, indeed to be particularly "musical" – to enjoy music and to respond to it at its deepest levels. Music is part of being human"*
> (Sacks, 2007, p. 347).

Musical therapy has had great success with the elderly, as well as with populations of individuals with impaired motor, cognitive and social function. For example there is striking evidence that musical rhythms can effectively be used for therapeutic purposes in the rehabilitation of movement disorders with differing neuropathology (Thaut et al., 1999). Importantly, the power of music is not dependent on familiarity with a musical work heard, as one Parkinsonian patient describes her need for music to help her move again, mentioned in Sacks' epic work 'Musicophilia' (2007). This patient expressed that with Parkinsonism her movements had become 'graceless', 'wooden' and 'mechanical', but when she became stuck or frozen, even the *imagining* of music aided her to 'dance out of the frame' and move freely and gracefully again. (Sacks, 2007, p. 253). Interestingly, Sacks (2007) also describes how this patient was able to benefit from walking beside another person, as she would easily and automatically move with another, "falling into their rhythm, their tempo, sharing their kinetic melody" (p. 253).

More specifically, some music therapy practices are now beginning to explore the use of our communicative musicality in therapeutic interventions, using its principles to engage enjoyable interactions between patient and therapist. For example, Mukherjee's (2008) work has explored the use of an adapted individual music therapy to facilitate and enhance communication and interaction skills in children with Autism, as impaired communication is a key diagnostic criteria of the Autistic Spectrum Disorders. Rather than employing preconceived forms of music, Mukherjee (2008) describes how "the 'musicality' of the event was prominent as the researcher and the child shared a common temporal ground while manifesting emotions of anticipation and pleasure with expressive movements and vocalizations" (p. 273). Just as two musicians may 'meet' musically by listening for and synchronising their musical expressions together to form a satisfying musical performance, Mukherjee's (2008) therapeutic techniques were used to encourage the children to engage with another by seeking sympathy for their feelings and motives in order to share an 'emotional narrative' (Stern, 1985).

2.7 Educational implications

In the musical education realm, this work has several important implications. In the first instance, furthered understanding of the way musicians perform expressively together in time could be used to improve performance techniques or enhance performance prowess by illustrating the importance of being a sympathetic and sensitive player, or of focusing one's attention on the micro-temporal or participatory timing aspects of musical play. But the question is, at the level of pulse, should we be showing young musicians that some of the great masters perform with considerable variation and are effectively 'sloppy'? Knowing more about the practice is not necessarily useful for the doing of our practices, and may even be damaging: "Quite the contrary; too much consciousness of 'how to groove' can get in the way" (Keil, n.d.). Prögler (1995) tackles this question in detail: "Can pleasure, play and "precise looseness" be taught at all, or are we teachers simply responsible for making the best grooves available daily and encouraging participation in them by having a very good time ourselves?" (p. 50). I would agree with Prögler's intuition, but not due to the fact that a playful 'looseness' is too difficult to be taught, rather because it is reflective of our inherently communicative motivations to play with time together.

3 Concluding remarks

This thesis contributes to a recent shift towards dynamic, temporally-grounded and embodied approaches to the study of human communication, by exploring the interpersonal aspects of timing in a musical ensemble, the ways in which musical expression is dynamically co-constructed in time.

Good time in jazz improvisation is much more than a means of keeping in step and adhering to the rules of the game. Musical coordination with others is not only the result of 'accurate synchronisation' between individual performances, it is also a collaborative endeavour that holds aesthetic value in itself (Gratier, 2008). A musical work deemed a success – like a conversation gone well – will always be the result of a negotiation of multiple aesthetic ideals, between musicians who have been listening to and sharing with each other and challenging their own ideals along the way.

Despite the commonly-held belief that jazz musicians can and do play perfectly and impressively together, it has been illustrated here that an experience of good time comes from knowing how to play around time, negotiating the musical beat in the moment with others as a reflection of both the culture and temperament of its musical collaborators. In a sense, jazz rhythm section negotiation is at once elastic, sociable and adventurous. Musicians are so very much in control of their musical output at various level of timing that the gaps left between them must be there to *say something*.

Furthermore, there is a highly social and moral dimension to the process of setting up and maintaining groove (Duranti & Burrell, 2004; Monson, 1996). Musicians not only push and pull at the beat because they have learnt to do so through an understanding of the culturally-constructed musical conventions of playing with style. Musicians do this because negotiating at the pulse level is the means by which they inherently express meaning to others and share meaning with them in time. Participatory timing is based upon the very foundations of social communication, intrinsically involved in negotiating pulse-level motives, building projected futures, and shaping performances into meaningful stories shared over time.

The study of jazz, from a cognitive psychology perspective, is still in its infancy. Nonetheless, mature manifestations of musical interaction such as jazz performance have a great deal to offer both music-lover and psychologist alike. Only by investigating improvisatory musical genres, in which the rhythmic patterning of inner motives to communicate musically with others is brought to the stage, are we able to 'say something' ourselves about the dynamic process of musical participation. Many musicians, critics and fans might resist such a theoretical approach to an appreciation of jazz, believing that study would only belittle its exquisitely subtle temporality and effect. But rest assured: despite being able to describe the details of great musical works and performances, one can still be *moved* by the music. This returns us to William James' quote introduced at the beginning of this thesis that suggests we should be 'effectively occupying' a place in our lives. This can be achieved by taking 'time out of the mind', and placing it back into our musically inclined bodies, in order to create and exchange meaningful stories with others in time.

List of Tables

List of Figures

References

Argyle, M. (1976). *Gaze and Mutual Gaze.* Cambridge: Cambridge University Press.

Aschersleben, G. (2002). Temporal Control of Movements in Sensorimotor Synchronization. *Brain & Cognition, 48*, 66-79.

Aschersleben, G. (2003). Effects of Training on the Timing of Repetitive Movements. In S. P. Shohov (Ed.), *Advances in Psychology Research, 23* (pp. 15-30). Huntington, NY: Nova Science.

Ashley, R. (2002). Don't Change a Hair for Me: The Art of Jazz Rubato. *Music Perception, 19*(3), 311-322.

Ashley, R. (2009). Musical Improvisation. In S. Hallam, I. Cross & M. Thaut (Eds.), *The Oxford Handbook of Music Psychology* (pp. 413-220). Oxford, New York: Oxford University Press.

Astin, P. (2010). *Some Ideas about the Language of Music as Expressing Our Human Essence*, Retrieved from www.Paulastin.blogspot.com, posted: 24/11/2010.

Austin, J. L. (1962). *How to Do Things with Words: Second Edition.* Oxford: Oxford University Press.

Baaren, R. B., Chartrand, T. L., Maddux, W. W., Bouter, C. D. & Knippenberg, A. V. (2003). It Takes Two to Mimic: Behavioural consequences of self-construals. *Journal of Personality and Social Psychology, 84*(5), 1093-1102.

Bailey, D. (1992). *Improvisation: Its Nature and Practise in Music.* United States of America: Da Capo Press.

Ball, P. (2010a). One World Under a Groove. *New Scientist, 206*(2759), 30-33.

Ball, P. (2010b). *The Music Instinct.* Oxford, New York: Oxford University Press.

Barker, R. G. (1968). *Ecological Psychology.* Stanford: Stanford University Press.

Baruch C. & Drake C. (1997). Tempo Discrimination in Infants. *Infant Behavior and Development, 20*(4), 573-577.

Bateson, M. C. (1979). The Epigenesis of Conversational Interaction: A personal account of research development. In M. Bullowa (Ed.), *Before Speech: The beginning of human communication* (pp. 63–77). London, England: Cambridge University Press.

Becker, H. (1963). *Outsiders: Studies in the Sociology of Deviance.* New York: The Free Press.

Becker, H. (1986). *Doing Things Together.* Evanston: Northwestern University Press.

Becker, H. S. (2000). The Etiquette of Improvisation. *Mind, Culture, and Activity, 7*(3), 171-176.

Benadon, F. (2006). Slicing the Beat: Jazz eighth-notes as expressive microrhythm. *Ethnomusicology, 50*, 73-98.

Bengtsson, I. & Gabrielsson, A. (1977). Rhythm Research in Uppsala. *Kungl. Musikaliska Akademiens Skriftserie, 17,* 19-56.

Bengtsson, S. L., Ullén, F., Ehrsson, H. H., Hashimoto, T., Kito, T., Naito, E., Forssberg, H. & Sadato, H. (2009). Listening to Rhythms Activates Motor and Premotor Cortices. *Cortex, 45*(1), 62-71.

Benzon, W. L. (2001). *Beethoven's Anvil: Music in mind and culture.* Oxford: Oxford University Press.

Berliner, P. F. (1994). Thinking in Jazz: The infinite art of improvisation. Chicago: The University of Chicago Press.

Bernstein, N. A. (1967). *The Co-ordination and Regulation of Movements.* Oxford: Pergamon Press.

Bilmes, J. A. (1993). *Timing is of the Essence: Perceptual and computational techniques for representing, learning and reproducing expressive timing in percussive rhythm.* Unpublished Master's Thesis, Massachusetts's Institute of Technology, Cambridge.

Birdwhistell, R. (1952). *Introduction to Kinesics: An Annotation System for the Analysis of Body Motion and Gesture.* Washington, DC: Foreign Service Institute.

Bjorkvold, J. R. (1992). *The Muse Within: Creativity and communication, song and play from childhood through maturity.* New York: Harper Collins Publishers.

Blacking, J. (1976). *How Musical is Man?* Faber: London.

Brazelton, T. B., Koslowski, B. & Main, M. (1974). The Origins of Reciprocity: The early mother-infant interaction. In M. Lewis & L.A. Rosenblum (Eds.), *The Effect of the Infant on its Caregiver* (pp. 49-76). New York: Wiley.

Brislin, R. W. & Kim, E. S. (2003). Cultural Diversity in People's Understanding and Uses of Time. *Applied Psychology, 52*(3), 363–382.

Broomhead, P. (2001). Individual Expressive Performance: Its Relationship to Ensemble Achievement, Technical Achievement, and Musical Background. *Journal of Research in Music Education, 49*(1), 71-84.

Broughton, M. & Stevens, C. (2009). Music, Movement and Marimba: An Investigation of the role of movement and gesture in communicating musical expression to an audience. *Psychology of Music, 37*, 137-153.

Brown, P. (1979). An Enquiry into the Origins and Nature of Tempo Behaviour. *Psychology of Music, 7*, 19-35.

Brown, S. (2000). Evolutionary Models of Music: From sexual selection to group selection. In

F. Tonneau & N.S. Thompson (Eds.), *Perspectives in Ethology 13: Behaviour, Evolution and Culture* (pp. 231-281). New York: Plenum Publishers.

Burnard, P. (2002). Investigating Children's Meaning-Making and the Emergence of Musical Interaction in Group Improvisation. *British Journal of Music Education, 19*(2), 157-172.

Busse, W. G. (2002). Toward Objective Measurement and Evaluation of Jazz Piano Performance Via MIDI-Based Groove Quantize Templates. *Music Perception, 19*(3), 443-461.

Butler, M. J. (2006). *Unlocking the Groove: Rhythm, meter and musical design in electronic dance music.* Bloomington, Indianapolis: Indiana University Press.

Butterfield, M. W. (2010). Participatory Discrepancies and the Perception of Beats in Jazz. *Music Perception, 27*(3), 157–175.

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

Chartrand, T. L. & Bargh, J. A. (1999). The Chameleon Effect – The perception-behaviour link and social interaction. *Journal of Personality and Social Psychology, 76*(6), 893-910.

Chela-Flores, B. (1994). On the Acquisition of English Rhythm: Theoretical and practical issue. *International Review of Applied Linguistics, 32*, 232-242.

Cherry, E. C. (1953). Some Experiments on the Recognition of Speech, With One or Two Ears. *Journal of the Acoustical Society of America, 25*, 975-979.

Chomsky, N. (1957). *Syntactic Structures.* The Hague: Mouton & Co.

Chomsky, N. (1968). *Language and Mind.* New York: Harcourt, Brace & World.

Clark, H. H. (2004). Pragmatics of Language Performance. In L. R. Horn & G. Ward (Eds.) *Handbook of Pragmatics* (pp. 365-382). Oxford: Blackwell.

Clark, H. H., & Brennan, S. A. (1991). Grounding in Communication. In L. B. Resnick, J.M. Levine, & S.D. Teasley (Eds.), *Perspectives on Socially Shared Cognition (*pp. 127-149). Washington: APA Books.

Clarke, E. F. (1987). Categorical Rhythm Perception, an Ecological Perspective. In A. Gabrielsson (Ed.), *Action and Perception in Rhythm and Music* (pp. 19-33). Sweden, Royal Swedish Academy of Music, No. 55.

Clarke, E. F. (1993). Imitating and Evaluating Real and Transformed Musical Performances. *Music Perception, 10*(3), 317.

Clarke, E. F. (1999). Rhythm and Timing in Music. In D. Deutsch (Ed.), *Psychology of Music, 2nd Edition* (pp. 473-500). University of California, San Diego: Academic Press.

Clarke, E. F. & Krumhansl, C. L. (1990). Perceiving Musical Time. *Music Perception, 7*, 213-

252.

Clayton, M. (1986). *Coordination Between Players in Musical Performance.* Unpublished Doctoral Dissertation, Edinburgh University, UK.

Clayton, M., Sager, R. & Will, U. (2004). In Time With the Music: The concept of entrainment and its significance for ethnomusicology. *ESEM CounterPoint, 1*, 3-45.

Clynes, M. (1977). *Sentics: The Touch of Emotions.* New York: Doubleday.

Clynes, M. (1986). When Time is Music. In J. R. Evans & M. Clynes (Eds.), *Rhythm in Psychological, Linguistic and Musical Processes* (pp. 169-182). Springfield, Illinois: Charles C. Thomas Publisher.

Clynes, M. & Walker, J. (1986). Music as Time's Measure. *Music Perception, 4*, 85–120.

Collier, G. L. & Collier, J. L. (1994). An Exploration of the Use of Tempo in Jazz. *Music Perception, 11*(3), 219-242.

Collier, G. L. & Collier, J. L. (1996). Microrhythms in Jazz: A review of papers. *Annual Review of Jazz Studies, 3*, 117-139.

Collier, G. L. & Collier, J. L. (2002a). A Study of Timing in Two Louis Armstrong Solos. *Music Perception, 19*(3), 463-483.

Collier, G. L. & Collier, J. L. (2002b). Introduction. *Music Perception, 19*(3), 279-284.

Condon, W. S. (1977). A Primary Phase in the Organization of Infant Responding Behavior. In H. R. Schaffer (Ed.), *Studies in Mother-Infant Interaction* (pp. 153-175). New York: Academic Press.

Condon, W. S. (1986). Communication: Rhythm and Structure. In J. R. Evans & M. Clynes (Eds.), *Rhythm in Psychological, Linguistic and Musical Processes* (pp. 55-78). Smithfield, Illinois: Charles C. Thomas Publisher.

Condon, W. S. & Ogston, W. D. (1966). Sound Film Analyses of Normal and Pathological Behavior Patterns. *Journal of Nervous and Mental Disease, 143*, 338-347.

Condon, W. S. & Sander, L. W. (1974). Neonate Movement is Synchronised with Adult Speech: Interactional Participation and Language Acquisition. *Science, 183*, 99-101.

Cooke, D. (1959). *The Language of Music.* Oxford: Oxford University Press.

Cook, N. (1990). *Music, Imagination and Culture.* Oxford: Clarendon.

Cook, N. (2001). Theorizing Musical Meaning. *Music Theory Spectrum, 23*(2), 170-195.

Cross, I. (2001). Music, Cognition, Culture and Evolution. *Annals of the New York Academy of Sciences, 930*, 28-42.

Cross, I. & Morley, I. (2009). The Evolution of Music: Theories, definitions and the nature of the evidence. In S. Malloch & C. Trevarthen (Eds.), *Communicative Musicality: Exploring the basis of human companionship* (pp. 61-82). Oxford: Oxford University Press.

Csikszentmihalyi, M. (1990). Flow: *The psychology of optimal experience.* New York: Harper & Row.

Csikszentmihalyi, M. (1997). *Finding Flow: The psychology of engagement with everyday life.* New York: HarperCollins.

Dahl, R. E. (1996). The Regulation of Sleep and Arousal: Development and psychopathology. *Development and Psychopathology, 8*(1), 3-27.

Dahl, S. (2006). *On the Beat: Human movement and timing in the production and perception of music.* Unpublished Doctoral Thesis, Royal Institute of Technology, Stockholm, Sweden.

Dalla-Bella, S. & Peretz, I. (2003). Congenital Amusia Interferes with the Ability to Synchronise with Music. *Annals of the New York Academy of Sciences, 999*, 166-169.

Damasio, A. R. (1999). *The Feeling of What Happens: Body, emotion and the making of consciousness.* London: Heinemann.

Davidson, J. (1993). Visual Perception of Performance Manner in the Movements of Solo Musicians. *Psychology of Music, 21*, 103-113.

Davidson, J. W. & Good, J. M. M. (2002). Social and Musical Co-ordination Between Members of a String Quartet: An Exploratory Study. *Psychology of Music, 30(*2), 186–201.

De Gelder, B. (2006). Towards the Neurobiology of Emotional Body Language. *Nature Review of Neuroscience, 7*, 242–9.

De Jaegher, H. (2006). *Social Interaction Rhythm and Participatory Sense-Making.* Unpublished Doctoral Thesis, University of Sussex.

Delavenne, A. (2011). *De l'Intimité à la Complicité: La chanson-action comme organisateur de l'attention chez le bébé de trois à six mois.* Unpublished Doctoral Thesis, Nanterre University, Paris.

Delavenne, A., Gratier, M., Devouche, E. & Apter, G. (2008). Phrasing and Fragmented Time in "Pathological" Mother-Infant Vocal Interaction. *Musicae Scientiae, Special Issue 2008*, 47-70.

Demany, L. (1982). Auditory Stream Segregation in Infancy. *Infant Behaviour and Development, 5*, 261-276.

Desain, P. & Honing, H. (1994). Does Expressive Timing in Music Performance Scale Proportionally with Tempo? *Psychological Research, 56*(4), 285-292.

Devouche, E. & Gratier M. (2001). Microanalyse du Rythme Dans les Echanges Vocaux et Gestuels Entre la Mère et son Bébé de 10 Semaines. *Devenir, 13*(2), 55-82.

Dixon, S. (2001). Automatic Extraction of Tempo and Beat From Expressive Performances. *Journal of New Music Research, 30*(1), 39–58.

Donald, M. (1999). Preconditions for the Evolution of Protolanguages. In M. C. Corballis & S. E. G. Lea (Eds.), *The Descent of Mind: Psychological perspectives on hominid evolution* (pp. 138-154). Oxford: Oxford University Press.

Donin, N. (2004). Towards Organised Listening: Some aspects of the 'Signed Listening' project, Ircam. *Organised Sound, 9*(1), 99–108.

Donin, N. (2007). Analyser la Musique en Acte et en Situation. *Doce Notas Preliminares, 19-20*, 300-315.

Drake, A. H. (1968). An Experimental Study of Selected Variables in the Performance of Musical Durational Notation. *Journal of Research in Music Education, 16,* 329-338.

Drake, C. & Botte, M.-C. (1993). Tempo Sensitivity in Auditory Sequences: Evidence for a multiple-look model. *Perception & Psychophysics, 54*(3), 277-286.

Drake, C. & Palmer, C. (1993). Accent Structures in Music Performance. *Music Perception, 10*(3), 343-378.

Drake, C., Penel, A. & Bigand, E. (2000). Tapping in Time with Mechanically and Expressively Performed Music. *Music Perception, 18*, 1-24.

Drewing, K., Li, S.-C., & Aschersleben, G. (in press). Sensorimotor Synchronization Across the Lifespan. *International Journal of Behavioral Development.*

Duranti, A. & Burrell, K. (2004). Jazz Improvisation: A Search for Hidden Harmonies and a Unique Self. *Ricerche di Psicologia, 27*(3), 71-101.

Eagleman, D. M., Tse, P. U., Buonomano, D., Janssen, P., Nobre, A. C. & Holcombe, A. O. (2005). Time and the Brain: How Subjective Time Relates to Neural Time. *The Journal of Neuroscience, 25*(45), 10369-10371.

Edgar, A., & Sedgwick, P. (2002). *Cultural Theory: The key concepts.* (Eds.). London: Routledge.

Ekman, P. (1992). *Telling Lies: Clues to deceit in the marketplace, politics, & marriages.* New York: W. W. Norton.

Ellis, M. C. (1991). An Analysis of "Swing" Subdivision and Asynchronization in Three Jazz Saxophonists. *Perceptual and Motor Skills*, *73*, 707-791.

Epstein, D. (1995). *Shaping Time: Music, the brain and performance*. New York: Schirmer.

Ericsson, K. A. & Kintsch, W. (1995). Long-term Working Memory. *Psychological Review, 102*, 211-245.

Falk, J. (1980). The Conversational Duet. *Proceedings of the Sixth Annual Meeting of the Berkeley Linguistics Society,* 507-514.

Farnsworth, P. R. (1969). *The Social Psychology of Music.* Ames, Iowa: Iowa State University Press.

Feldman, R. (2006). From Biological Rhythms to Social Rhythms: Physiological Precursors of Mother–Infant Synchrony. *Developmental Psychology, 42*(1), 175-188.

Feldman, R., Magori-Cohenc, R., Galili, G., Singerb, M. & Louzounc, Y. (2011). Mother and Infant Coordinate Heart Rhythms through Episodes of Interaction Synchrony. *Infant, Behavior and Development, 34*, 359-577.

Flores, E. O. (2010). Estructuras Subyacentes a la Copla Flamenca y Figuras Literarias de Variaciones. *Ogigia : Revista Electrónica de Estudios Hispánicos, 8*, 33-45.

Fraboulet, A. (2010). *Corps et Interprétation: Lorsque que le corps pianistique raconte une histoire.* Unpublished Doctoral Dissertation. Nanterre University, Paris.

Fraisse, P. (1956). *Les Structures Rythmiques : Etude psychologique.* Louvain : Publications Universitaires de Louvain.

Fraisse, P. (1967). *Psychologie du Temps.* Paris : Presses Universitaires de France.

Fraisse, P. (1984). Perception and Estimation of Time. *Annual Review of Psychology, 35*, 1–36.

Freeman, W. J. (2000a). Perception of Time and Causation Through the Kinesthesia of Intentional Action. *Cognitive Processing, 1*, 18-34.

Freeman, W. J. (2000b). A Neurobiological Role of Music in Social Bonding. In N. L. Wallin, B. Merker & S. Brown. (Eds.) *The Origins of Music* (pp. 411-424). Cambridge, MA: MIT Press.

Friberg, A. (1995). *A Quantitative Rule System for Musical Performance.* Unpublished Doctoral Dissertation, Royal Institute of Technology, Stockholm, Sweden.

Friberg, A. & Sundberg, J. (1995). Time Discrimination in a Monotonic, Isochronous Sequence. *Journal of the Acoustical Society of America, 98*, 2524-2531.

Friberg, A. & Sundström, A. (2002). Swing Ratios and Ensemble Timing in Jazz Performance: Evidence for a Common Rhythmic Pattern. *Music Perception, 19*(3), 333-349.

Gabrielsson, A. (1988). Timing in Music Performance and its Relations to Music Experience. In J.A. Sloboda (Ed.), *Generative Processes in Music* (pp. 27-51). Oxford: Clarendon Press.

Gabrielsson, A. (1995). Expressive Intention and Performance. In R. Steinberg (Ed.), *Music and the Mind Machine* (pp. 35-47). Berlin: er-Verlag.

Gabrielsson, A. (1998). Verbal Description of Music Experience. In Suk Won Yi (Ed.), *Proceedings of the 5th International Conference on Music Perception and Cognition* (pp. 271-276). Seoul, Korea: Seoul National University.

Gabrielsson, A. (1999). The Performance of Music. In D. Deutsch (Ed.), *The Psychology of*

Music, (2nd ed.). (pp. 501-602). San Diego: Academic Press.

Gabrielsson, A., & Juslin, P. N. (1996). Emotional Expression in Music Performance: Between the performer's intention and the listener's experience. *Psychology of Music, 24*(1), 68-91.

Gérard, C., & Rosenfeld, M. (1995). Pratique Musicale et Régulations Temporelles. *L'Année Psychologique, 95*, 571-591.

Gibson, J. J. (1979). *The Ecological Approach to Visual Perception.* Boston: Houghton Mifflin.

Glass, L. (2001). Synchronization and Rhythmic Processes in Physiology. *Nature, 410*, 277-284.

Goebl, W. (2001). Melody Lead in Piano Performance: Expressive device or artefact? *Journal of the Acoustical Society of America, 110*, 563-572.

Goebl, W. & Palmer, C. (2009). Synchronization of Timing and Motion Among Performing Musicians. *Music Perception, 26*(5), 427-438.

Goffman, E. (1974). *Frame Analysis: An essay on the organisation of experience.* Boston: Northeastern University Press.

Gogate, L. J., Bahrick, L. E. & Watson, J. D. (2000). A Study of Multimodal Motherese: The role of temporal synchrony between verbal labels and gestures. *Child Development, 71*(4), 878-894.

Goodwin, C. (1981). *Conversational Organization: Interaction between speakers and hearers.* New York: Academic Press.

Goodwin, C. (2002). Time in Action. In 'Repertoires of Timekeeping in Anthropology', *Current Anthropology, Special issue, 43,* 19-35.

Gordon, J. W. (1987). The Perceptual Attack Time of Musical Tones. *Journal of the Acoustical Society of America, 82*, 88-105.

Grahn, J. A. & Brett, M. (2009). Impairment of Beat-Based Rhythm Discrimination in Parkinson's Disease. *Cortex, 45*(1), 54-61.

Gratier, M. (2000). Expressions of Belonging: The effect of acculturation on the rhythm and harmony of mother-infant vocal interaction. In 'Rhythms, Musical Narrative, and the Origins of Human Communication', *Musicae Scientiae, Special Issue 1999-2000*, 93-122.

Gratier, M. (2003). Expressive Timing and Interactional Synchrony Between Mothers and Infants: Cultural similarities, cultural differences, and the immigration experience. *Cognitive Development, 18*, 553-554.

Gratier, M. (2007). Musicalité, Style et Appartenance. In M. Imberty & M. Gratier (Eds), *Temps, Geste et Musicalité* (pp. 69-100). Paris: L'Harmattan.

Gratier, M. (2008). Grounding in Musical Improvisation: Evidence from Jazz Performances. *Musicae Scientiae, Special Issue 2008,* 71-110.

Gratier, M. & Devouche, E. (2011). Imitation and Repetition of Prosodic Contour in Vocal Interaction at 3 Months. *Developmental Psychology, 47*(1), 67-76.

Gratier, M. & Stevanovic, K. (2008). In the Recording Studio: A music psychology study of jazz ensemble interaction. Proceedings, *Leeds International Jazz Conference,* U.K.

Gratier, M. & Trevarthen, C. (2008). Musical Narrative and Motives for Culture in Mother-Infant Vocal Interaction. *Journal of Consciousness Studies, 15*(10/11), 122-158.

Greenfield, M. D. & Roisen, I. (1993). Katydid Synchronous Chorusing is an Evolutionarily Stable Outcome of Female Choice. *Nature, 364*, 618-620.

Gridley, M. C. (1985). *Jazz Styles: History and analysis.* Englewood Cliffs, New Jersey: Prentice-Hall.

Handel, S. (1989). *Listening.* Cambridge, MA: MIT Press.

Hanslick, E. (1891). *The Beautiful in Music*, transl. G. Cohen. London: Novello, Ewer & Co. Retrieved from http://www.ebooksread.com, 14/02/2010.

Heidegger, M. (1962). *Sein und Zeit* (Being and Time), Translated by Blackwell Publishing. Oxford: Blackwell Publishing Ltd.

Himberg, T. (2006, August). Co-Operative Tapping and Collective Time-Keeping: Differences of timing accuracy in duet performance with human or computer partner. Paper presented at the *9th International Conference on Music Perception and Cognition*, Bologna, Italy.

Hirsh, I. J. (1959). Auditory Perception of Temporal Order. *Journal of the Acoustical Society of America, 31*, 759-767.

Hodson, R. (2007). Interaction, Improvisation, and Interplay in Jazz. New York: Routledge.

Honing, H. (2001). From Time to Time: The Representation of Timing and Tempo. *Computer Music Journal, 24*(3), 50-61.

Honing, H. (2006). Evidence for Tempo-Specific Timing in Music Using a Web-Based Experimental Setup. *Journal of Experimental Psychology: Human Perception and Performance, 32*(3), 780-786.

Hove, M. J., Keller, P. E. & Krumhansl, C. L. (2007). Sensorimotor Synchronization with Chords Containing Tone-Onset Asynchronies. *Perception & Psychophysics, 69*(5), 699-708.

Hove, M. J. & Risen, J. L. (2009). It's All in the Timing: Interpersonal synchrony increases affiliation. *Social Cognition, 27*(6), 949-961.

Hugo, Victor (1864). *William Shakespeare.* Librairie Internationale: LaCroix, Verboeckhoven & Co.

Huron, D. (2006). *Sweet Anticipation: Music and the Psychology of Expectation.* Cambridge: MIT Press.

Imberty, M. (1979). *Entendre la Musique: Sémantique psychologique de la musique, Tome 1*. Paris: Dunod.

Imberty, M. (1981). *Les Ecritures du Temps: Sémantique psychologique de la musique, Tome 2*. Paris: Dunod.

Imberty, M. (1991). How Do the Performer and the Listener Organise the Temporal Progression of a Musical Work? Analysis, memorisation, and interpretation. *Psychologica Belgica, 31*(2), 173-195.

Imberty, M. (2003). Music, Biology, Cognition : Issues about XX century music. *Cognitive Processing, 4*(3), 5-22.

Imberty, M. (2005). *La Musique Creuse le Temps. De Wagner à Boulez: Musique, psychologie, psychanalyse.* Paris: L'Harmattan.

Istok, E., Tervaniemi, M., Friberg, A., & Seifert, U. (2008). Effects of Timing Cues in Music Performances on Auditory Grouping and Pleasantness Judgments. In *The 10th International Conference on Music Perception and Cognition,* Sapporo, Japan.

Iyer, V. (1998). *Microstructures of Feel, Macrostructures of Sound: Embodied cognition in west African and African-American musics.* Unpublished doctoral dissertation, University of California, Berkeley.

Iyer, V. (2002). Embodied Mind, Situated Cognition, and Expressive Microtiming in African-American Music. *Music Perception, 19*(3), 387-414.

Iyer, V. (2004). Improvisation, Temporality and Embodied Experience. *Journal of Consciousness Studies, 11*(3-4), 159-173.

Iyer, V., Bilmes, J., Wright, M. & Wessel, D. (1997). A Novel Representation for Rhythmic Structure. *International Computer Music Conference Proceedings,* Retrieved from http://www.cnmat.berkeley.edu/ICMC97/papers-html/Rhythm.html, 14/02/2010.

James, W. (1890). *Principles of Psychology.* New York: H Holt & Co.

Janata, P. & Grafton, S.T. (2003). Swinging in the Brain: Shared Neural Substrates for Behaviours Related to Sequencing and Music. *Nature Neuroscience, 6*(7), 682-687.

Jensenius, A. R., Godøy, R. I. & Wanderley, M. M. (2005). Developing Tools for Studying Musical Gestures Within the MAX/MSP/JITTER Environment. *Musicology, 3*, 3-6.

Johnson, M. (2007). *The Meaning of the Body: Aesthetics of Human Understanding.* Chicago: Unversity of Chicago Press.

Jones, M. R. (1976). Time, Our Lost Dimension: Toward a new theory of perception, attention, and memory. *Psychological Review, 83*(5), 323-355.

Jungers, M. K., Palmer, C., & Speer, S. R. (2002). Time After Time: The Coordinating influence of tempo in music and speech. *Cognitive Processing, 1*, 21-35.

Juslin, P. N. & Laukka, P. (2003). Communication of emotions in vocal expression and music performance: different channels, same code? *Psychological Bulletin, 129*(5), 770-814.

Juslin, P. N. & Laukka, P. (2004). Expression, Perception and Induction of Musical Emotions: A Review and questionnaire study of everyday listening. *Journal of New Musical Research, 33*, 217–38.

Juslin, P. N. & Madison, G. (1999). The Role of Timing Patterns in Recognition of Emotional Expression From Musical Performance. *Music Perception*, *17*(2), 197-221.

Keele, S. W. (1968). Movement Control in Skilled Motor Performance. *Psychological Bulletin, 70,* 387-403.

Keil, C. (1987). Participatory Discrepancies and the Power of Music. *Cultural Anthropology, 2*(3), 275-83.

Keil, C. (1994). Motion and Feeling Through Music. In C. Keil & S. Feld (Eds.), *Music Grooves* (pp. 53-76). Chicago: The University of Chicago Press.

Keil, C. (1995). The Theory of Participatory Discrepancies: A Progress report. *Ethnomusicology, Special Issue: Participatory Discrepancies, 39*(1), 1-19.

Keil, C. (n.d.) *Groovology and the magic of other people's music.* Retrieved from http://musicgrooves.org/, 2/08/2008.

Keil, C. & S. Feld (1994). *Music Grooves.* Chicago: The University of Chicago Press.

Keller, P. E. & Repp, B. H. (2008). Multilevel Coordination Stability: Integrated goal representations in simultaneous intra-personal and inter-agent coordination. *Acta Psychologica, 128*(2), 378-386.

Kendall, R. A. & Carterette, E. C. (1990). The Communication of Musical Expression. *Music Perception, 8*(2), 129-163.

Kirschner, S. & Tomasello, M. (2009). Joint Drumming: Social context facilitates synchronization in preschool children. *Journal of Experimental Child Psychology, 102*, 299-314.

Kleinspehn-Ammerlahn, A., Riediger, M., Schmiedek, F., von Oertzen, T., Li, S-C. & Lindenberger, U. (2011). Dyadic Drumming Across the Lifespan Reveals a Zone of Proximal Development in Children. *Developmental Psychology, 47*(3), 632-644.

Konvalinka, I., Xygalatasa, D., Bulbuliac, J., Schjødta, U., Jegindøa, E.-M., Wallotd, S., Van Ordend, G. & Roepstorff, A. (2011). Synchronized arousal between performers and related spectators in a fire-walking ritual. *Proceedings of the National Academy of Sciences*: *Early Edition,* Retrieved from www.pnas.org/cgi/doi/10.1073/pnas.1016955108, 8/8/2011.

Krumhansl, C. L. & Jusczyk, P. W. (1990). Infants' Perception of Phrase Structure in Music. *Psychological Science, 1*(1), 70-73.

Kühl, O. (2008). *Musical Semantics.* Bern: Peter Lang.

Kuhn, T. L. (1974). Discrimination of Modulated Beat Tempo by Professional Musicians. *Journal of Research in Music Education, 22*, 270–277.

Lakoff, G. & Johnson, M. (1999). *Philosophy in the Flesh, The Embodied Mind and Its Challenges to Western Thought.* New York, Basic Books.

Langer, S. K. (1942). *Philosophy in a New Key: A Study in the Symbolism of Reason, Rite, and Art.* Harvard University Press: Cambridge.

Langer, S. K. (1953). *Feeling and Form: A theory of art developed from Philosophy in a New Key.* London: Routledge & Kegan Paul.

Large, E. W., Fink, P., & Kelso, J. A. S. (2002). Tracking Simple and Complex Sequences. *Psychological Research, 66*, 3-17.

Large, E. W. & Palmer, C. (2002). Perceiving Temporal Regularity in Music. *Cognitive Science 26*, 1-37.

Laukka, P. & Gabrielsson, A. (2000). Emotional Expression in Drumming Performance. *Psychology of Music, 28*, 181-189.

LaRue, J. (1970). *Guidelines for Style Analysis: A Comprehensive outline of basic principles for the analysis of musical style.* New York: W. W. Norton & Company.

Lee, D. N. (1998). Guiding Movement by Coupling Taus. *Ecological Psychology, 10*(3-4), 221-250.

Lee, D. N. & Schögler, B. (2009). Tau in Musical Expression. In S. Malloch & C. Trevarthen (Eds.), *Communicative Musicality: Exploring the basis of human companionship* (pp. 83-104). Oxford: Oxford University Press.

Lerdahl, F. (1996). Calculating Tonal Tension. *Music Perception,* 13, 319–363.

Lerdahl, F. & Jackendoff, R. (1983). *A Generative Theory of Tonal Music.* Cambridge: MIT Press.

Levitin, D. J. (2006). *This Is Your Brain on Music: The Science of a Human Obsession.* London: Atlantic Books.

Loehr, J. D., Large, E. W. & Palmer, C. (2011). Temporal Coordination in Music Performance: Adaptation to tempo change. *Journal of Experimental Psychology: Human Perception and Performance, 37*(4), 1292–1309.

Loehr, J. D. & Palmer, C. (2009a). Sequential and Biomechanical Factors Constrain Timing and Motion in Tapping. *Journal of Motor Behavior, 41*, 128-136.

Loehr, J. D. & Palmer, C. (2009b). Subdividing the Beat: Auditory and motor contributions to synchronization. *Music Perception, 26*, 415-425.

London, J. (2002). Cognitive Constraints on Metric Systems: Some Observations and Hypotheses. *Music Perception, 19*(4), 529-550.

London, J. (2004). *Hearing in Time, Psychological Aspects of Musical Meter.* Oxford: Oxford University Press.

Lortat-Jacob, B. (1987). *L'improvisation dans les Musiques de Tradition Orale.* Paris: SELAF.

Lortat-Jacob, B. (1998). *Chants de Passion: Au Cœur d'une confrérie de Sardaigne*. Paris: Les Editions du Cerf.

Luck, G. & Nte, S. (2008). An Investigation of Conductors' Temporal Gestures and Conductor-Musician Synchronization, and a First Experiment. *Psychology of Music, 36*, 81-99.

MacDuff, I. (2006). Your Pace or Mine? Culture, Time, and Negotiation. *Negotiation Journal, 22*(1), 31-45.

Mace, Thomas. (1676). *Musick's Monument.* Retrieved from http://www.archive.org/details/musicksmonumento00mace, 29/09/2011.

Macmillan, N. A. & Creelman, C. D. (2005). *Detection Theory: A User's Guide.* New Jersey: Laurence Erlbaum Associates Inc. Publishers.

Madison, G. (1998). Acuity as a Function of Interonset Interval: Similarities between perception and production of isochronic sound sequences. In E. Szelag & E. Pöppel (Eds.), *Proceedings of Time and Timing in Neural Systems* (pp. 16-18). Strzekecino, Poland: Nencki Institute of Experimental Biology.

Madison, G. (2000). Properties of Expressive Variability Patterns in Music Performance. *Journal of New Music Research, 29*(4), 335-356.

Madison, G. (2001). Variability in Isochronous Tapping: Higher-order dependencies as a function of inter tap interval. *Journal of Experimental Psychology: Human Perception and Performance, 27*(2), 411-422.

Madison, G. (2006). Experiencing Groove Induced by Music: Consistency and phenomenology. *Music Perception, 24*(2), 201-208.

Madison, G., & Merker, B. (2002). On the Limits of Anisochrony in Pulse Attribution. *Psychological Research, 66*, 201-207.

Maes, P. J., Leman, M., Lesaffre, M., Demey, M. & Moelants, D. (2010). From Expressive Gesture to Sound: The Development of an embodied mapping trajectory inside a musical interface. *Journal on Multimodal User Interfaces, 3*(1-2), 67-78.

Malhotra, V. A. (1981). The Social Accomplishment of Music in a Symphony Orchestra: A phenomenological analysis. *Qualitative Sociology, 4*(2), 102-125.

Malloch, S. N. (1999). Mothers and Infants and Communicative Musicality. *Musicæ Scientiæ, Special Issue: Rhythm, musical narrative, and the origins of human communication, (1999-2000),* 29-57.

Malloch, S. N. & Trevarthen, C. (2009). Musicality: Communicating the vitality and interests of life. In S. Malloch & C. Trevarthen (Eds.), *Communicative Musicality: Exploring the basis of human companionship* (pp. 1-12). Oxford: Oxford University Press.

Männel, C., Neuhaus, C. & Friederici, A. D. (2007). *5-month-olds get it: ERP components of phrase structure processing in language and music.* Talk presented at Language and Music as Cognitive Systems. UK, 13/05/2007.

Marsh, K. L., Richardson, M. J. & Schmidt, R. C. (2009). Social Connection Through Joint Action and Interpersonal Coordination. *Topics in Cognitive Science, 1*, 320-339.

McFarland, D. H. (2001). Respiratory Markers of Conversational Interaction. *Journal of Speech, Language, and Hearing Research, 44*, 128–143.

McGuinness, A. (2005). *Microtiming Deviations in Groove.* Unpublished Master's Thesis, Australian National University.

McNeill, W. H. (1995). *Keeping Together in Time.* Cambridge, MA: Harvard University Press.

Mendonça, D. & William, A. W. (2004). Cognition in Jazz Improvisation: An Exploratory Study. Retrieved from: http://web.njit.edu/~mendonca/papers/CS04_Final.pdf, 24/01/2009.

Merker, B. (1999). Synchronous Chorusing and the Origins of Music. *Musicæ Scientiæ, Special Issue: Rhythm, musical narrative, and the origins of human communication, (1999-2000),* 59-73.

Merker, B. H., Madison, G. S. & Eckerdal, P. (2009). On the Role and Origin of Isochrony in Human Rhythmic Entrainment. *Cortex, 45*(1), 4-17.

Meyer, L. (1956). *Emotion and Meaning in Music.* Chicago, IL: University of Chicago Press.

Michon, J. A. (1967). *Timing in Temporal Tracking.* Assen, NL: Van Gorcum & Co.

Miell, D. & MacDonald, R. A. R. (2000). Children's Creative Collaborations: The importance of friendship when working together on a musical composition. *Social Development, 9*(3), 348-369.

Miyake, I. (1902). Researches on Rhythmic Activity. *Studies From the Yale Psychological Laboratory, 10*, 1-48.

Moelants, D. (2003). Dance Music, Movement and Tempo Preferences. In R. Kopiez, A.C. Lehmann, I. Wolther and C. Wolf (Eds.) *Proceedings of the 5th triennial ESCOM Conference* (pp. 649-652). Hanover: University of Music and Drama.

Molinari, M., Leggio, M. G. & Thaut, M. H. (2007). The Cerebellum and Neural Networks for Rhythmic Sensorimotor Synchronization in the Human Brain. *The Cerebellum, 6*(1), 18-23.

Molnar-Szakacs, I. & Overy, K. (2006). Music and Mirror Neurons: From motion to "e"motion. *Social Cognitive and Affective Neuroscience, 1*(3), 235-241.

Monson, I. (1995). Responses to Keil, Prögler, Alén. *Ethnomusicology, 39*(1), 87-89.

Monson, I. (1996). *Saying Something: Jazz improvisation and interaction*. Chicago: The University of Chicago Press.

Moran, N. S. (2007). *Measuring Musical Interaction: Analysing communication in embodied musical behaviour.* Unpublished doctoral dissertation, Open University, U.K.

Mukherjee, B. B. (2008). *Musical Interaction with Children with Autistic Spectrum Disorder In An Indian Context.* Unpublished Doctoral Thesis, University of Strathclyde.

Murray, L. & Trevarthen, C. (1985). Emotional Regulation of Interactions Between Two-month-olds and Their Mothers. In T. M. Field & N. A. Fox (Eds.), *Social Perception in Infants* (pp. 177-197). Norwood, NJ: Ablex.

Murray L. & Trevarthen C. (1986). The Infant's Role in Mother-Infant Communication. *Journal of Child Language, 13*, 15-29.

Narmour, E. (1991). The Top-Down and Bottom-Up Systems of Musical Implication: Building on Meyer's theory of emotional syntax. *Music Perception, 9*, 1–26.

Nattiez, J.-J. (1990). *Music and Discourse: Towards a semiology of music.* Princeton, NJ: Princeton University Press.

Naylor, G. M. (1992). A Laboratory Study of Interaction Between Reverberation, Tempo and Musical Synchronisation. *Acustica, 75*, 256-267.

Nazzi, T., Jusczyk, P. W. & Johnson, E. K. (2000). Language Discrimination by English Learning 5-month-olds: Effects of rhythm and familiarity. *Journal of Memory and Language, 43*, 1-19.

Nettl, B. (1974). Thoughts on Improvisation: A comparative approach. *The Musical Quarterly, 60,* 1.

Nusseck, M. & Wanderley, M. M. (2009). Music and Motion – How music-related ancilliary body movements contribute to the experience of music. *Music Perception 26*(4), 335–353.

Ochs, E. (1997). Narrative. In T. A. van Dijk (Ed.), *Discourse as Structure and Process* (pp. 185-207). London: Sage Publications.

Osborne, N. (2009). Towards a Chronobiology of Musical Rhythm. In S. Malloch & C. Trevarthen (Eds.), *Communicative Musicality: Exploring the basis of human companionship* (pp. 545-564). Oxford: Oxford University Press.

Overy, K. & Molnar-Scakacs, I. (2009). Being Together in Time: Musical experience and the mirror neuron system. *Music Perception, 26*(5), 489-504.

Overy, K. & Turner, R. (2009). The Rhythmic Brain. *Cortex, 45*(1), 1-3.

Palmer, C. (1989). Mapping Musical Thought to Musical Performance. *Journal of Experimental Psychology: Human Perception and Performance, 15*(2), 331-346.

Palmer, C. (1997). Music Performance. *Annual Review of Psychology, 48,* 115-138.

Palmer, C., Koopmans, E., Loehr, J. D., & Carter, C. (2009). Movement-Related Feedback and Temporal Accuracy in Clarinet Performance. *Music Perception, 26*, 439-449.

Panksepp, J. (1998). The Preconscious Substrates of Consciousness: Affective states and the evolutionary origins of the self. *Journal of Consciousness Studies, 5*, 566-582.

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

Parncutt, R. (1994). A Perceptual Model of Pulse Salience and Metrical Accent in Musical Rhythms. *Music Perception, 11*, 409-464.

Parsons, L. M. (2001). Exploring the Functional Neuroanatomy of Music Performance, Perception and Comprehension. *Annals of the New York Academy of Sciences, 930,* 211-231.

Patel, A. D. (2008). *Music, Language and the Brain*. Oxford: Oxford University Press.

Penel, A. & Drake, C. (1998). Sources of Timing Variations in Music Performance: A psychological segmentation model. *Psychological Research, 61*, 12-32.

Perlman, A. & Greenblatt, D. (1981). Miles Davis Meets Noam Chomsky: Some Observations on Jazz Improvisation and Language Structure. In W. Steiner (Ed.), *The Sign in Music and Language*. University of Texas Press: Austin.

Phillips-Silver, J. & Trainor, (2005). Feeling the Beat: Movement influences infant rhythm perception. *Science, 308*(5727), 1430.

Pieron, H. (1945). *La Sensation: Guide de Vie*. Paris: Gallimard.

Pöppel, E. & Wittmann, M. (1999). Time in the Mind. In R. Wilson & F. Keil (Eds.), *The MIT Encyclopedia of the Cognitive Sciences* (pp. 836–837). Cambridge, MA: MIT Press.

Pouthas, V. (1996). The Development of the Perception of Time and Temporal Regulation of Action in Infants and Children. In I. Deliège & J. Sloboda (Eds.), *Musical Beginnings: Origins and development of musical competence* (pp. 115-141). Oxford: Oxford University Press.

Povel, D.-J. (1977). Temporal Structure of Performed Music: Some preliminary observations. *Acta Psychologica, 41*, 309-320.

Pressing, J. (1987). Improvisation: Methods and Models. In J. Sloboda (Ed.), *Generative Processes in Music: The psychology of performance, improvisation and composition.* (pp.). Oxford: Clarendon Press.

Pressing. J. (2002). Black Atlantic Rhythm: It's Computational and Transcultural Foundations. *Music Perception, 19*(3), 285-310.

Prögler, J. A. (1995). Searching for Swing: Participatory Discrepancies in the Jazz Rhythm Section. *Ethnomusicology, Special Issue: Participatory Discrepancies, 39*(1), 21-54.

Provine, R. R. (2005). Yawning. *American Scientist, 93,* 532–539.

Rasch, R. (1979). Synchronization in Performed Ensemble Music, *Acustica, 43*, 121–131.

Rasch, R. A. (1988). Timing and Synchronization in Ensemble Performance. In J. A. Sloboda (Ed.), *Generative Processes in Music: The psychology of performance, improvisation and composition (*pp. 70-90). Oxford: Clarendon Press.

Reinholdsson, P. (1987). Approaching Jazz Performances Empirically: Some reflections on methods and problems. In A. Gabrielsson (Ed.), *Action and Perception in Rhythm and Music* (pp. 105-125). Stockholm: Royal Swedish Academy of music.

Reinholdsson, P. (1998). Making Music Together: An Interactionist perspective on small-group performance in jazz. *Studia Musicologica Upsaliensia, Nova Series 14*: Uppsala.

Repp, B. H. (1990). Patterns of Expressive Timing in Performances of a Beethoven Minuet by Nineteen Famous Pianists. *Journal of the Acoustical Society of America, 88*(2), 622-641.

Repp, B. H. (1992). Diversity and Commonality in Music Performance: An analysis of timing microstructure in Schumann's "Traumerei." *Journal of the Acoustical Society of America, 92,* 2546-2568.

Repp, B. H. (1994). Relational Invariance of Expressive Microstructure Across Global Tempo Changes in Music Performance: An exploratory study. *Psychological Research, 56*, 269-284.

Repp, B. H. (1997). Expressive Timing in a Debussy Prelude: A comparison of student and expert pianists. *Musicae Scientiae, 1*(2), 257-268.

Repp, B. H. (1998a). Obligatory "expectations" of expressive timing induced by perception of musical structure. *Psychological Research, 61*, 33-43.

Repp, B. H. (1998b). The Detectability of Local Deviations from a Typical Expressive Timing Pattern. *Music Perception, 15*(3), 265-289.

Repp, B. H. (1998c). Variations on a Theme by Chopin: Relations Between Perception and Production of Timing in Music. *Journal of Experimental Psychology: Human Perception and Performance, 24*(3), 791-811.

Repp, B. H. (1999a). Control of Expressive and Metronomic Timing in Pianists. *Journal of Motor Behavior, 31*, 145-164.

Repp, B. H. (1999b). Detecting Deviations from Metronomic Timing in Music: Effects of perceptual structure on the mental time keeper. *Perception & Psychophysics, 61*, 529-548.

Repp, B. H. (1999c). Relationships Between Performance Timing, Perception of Timing Perturbations and Perceptual-Motor Synchronisation in Two Chopin Preludes. *Australian Journal of Psychology, 51*(3), 188-203.

Repp, B. H. (2005). Sensorimotor Synchronization: A review of the tapping literature.

Psychonomic Bulletin & Review, 12(6), 969-992.

Repp, B. H. (2008). Metrical Subdivision Results in Subjective Slowing of the Beat. *Music Perception, 26*(1), 19-39.

Repp, B. H. (2010). Sensorimotor Synchronization and Perception of Timing: Effects of music training and task experience. *Human Movement Science, 29*(2), 200-213.

Repp, B. H. & Penel, A. (2004). Rhythmic Movement is Attracted More Strongly to Auditory Than to Visual Rhythms. *Psychological Research, 68*(4), 252-270.

Riley, J. (1997). *Beyond Bop Drumming*. New York: Manhattan Music.

Rizzolatti, G. & Craighero, L. (2004). The Mirror-Neuron System. *Annual Review of Neuroscience, 27*, 169-192.

Ronken, D. A. (1970). Monaural Detection of a Phase Difference Between Clicks. *Journal of the Acoustical Society of America, 47*, 1091-1099.

Rose, R. L. (1989). *An Analysis of Timing in Jazz Rhythm Section Performance.* Unpublished Doctoral Dissertation, The University of Texas, Austin.

Runeson, S. & Frykholm, G. (1983). Kinematic Specification of Dynamics as an Informational Basis for Person-and-Action Perception: Expectation, gender recognition, and deceptive intention. *Journal of Experimental Psychology, 112*(4), 585-615.

Sacks, O. (2007). *Musicophilia: Tales of Music and the Brain.* London, New York: Random House.

Sawyer, K. (1992). Improvisational Creativity: An analysis of jazz performance. *Creativity Research Journal, 5*(3), 253-263.

Sawyer, K. (2000). Improvisational Cultures: Collaborative Emergence and Creativity in Improvisation. *Mind, Culture and Activity, 7*(3), 180-185.

Sawyer, K. (2003). *Group Creativity: Music, theatre, collaboration*. Mawah, New Jersey: Lawrence Erlbaum.

Scheflen, A. E. (1963). Communication and Regulation in Psychotherapy. *Psychiatry, 26*(2), 126-136.

Schegloff, E. A. (1989). Reflections on Language, Development, and the Interactional Charater of Talk-in-Interaction. In M. H. Bornstein & J. S. Bruner (Eds.), *Interaction in Human Development* (pp. 139-153). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Scherer, K. R. (1985). Emotions can be Rational. *Social Science Information, 24*, 331-335.

Schippers, M. B., Roebroeck, A., Renkena, R., Nanettia, L. & Keysers, C. (2010). Mapping the Information Flow from One Brain to Another During Gestural Communication. *Proceedings of the National Academy of Sciences, 107*(20), 9388-9393.

Schlaug, G. (2001). The Brain of Musicians: A model for functional and structural adaptation. *Annals of the New York Academy of Sciences, 930*, 281-299.

Schmidt, R. C. & Richardson, M. J. (2008). Dynamics of Interpersonal Coordination. In A. Fuchs & V. Jirsa (Eds.), *Coordination: Neural, Behavioural and Social Dynamics* (pp. 281-308). Heidelberg: er-Verlag.

Schögler, B. W. (1999). Studying Temporal Co-ordination in Jazz Duets. In 'Rhythms, Musical Narrative, and the Origins of Human Communication' *Musicae Scientiae, Special Issue, 1999-2000,* 75-92.

Schögler, B. W. (2002). *The Pulse of Communication in Improvised Jazz Duets.* Unpublished Doctoral Thesis, University of Edinburgh.

Schögler, B. W. (2003). The Pulse of Communication in Improvised Music. In R. Kopiez, A. C. Lehmann, I. Wolther & C. Wolf (Eds.), *Proceedings of the5th triennial ESCOM conference* (pp. 574-577). Hanover University of Music and Drama, Germany.

Schögler, B. W. & Trevarthen, C. (2007). To Sing and Dance Together: From infants to jazz. In S. Bråten (Ed.), *On Being Moved: From mirror neurons to empathy* (pp. 281–302). Amsterdam, Philadelphia: John Benjamins Pub.

Schuller, G. (1989). *The Swing Era: The Development of Jazz in 1930-45.* New York: Oxford University Press.

Schulze, H., Cordes, A. & Vorberg, D. (2005). Keeping Synchrony While Tempo Changes: Accelerando and Rittardando. *Music Perception, 22*(3), 461-477.

Schutz, A. (1951). *Making Music Together.* In A. Broderson (Ed.)(1964), Collected Papers, Volume 2: Studies in Social Theory (pp. 159-178). The Hague, Martinus Nijhoff.

Schutz, A. (1967). *The Phenomenology of the Social World.* In G. W. F. Lehnert (Trans.)(3rd ed.). London: Heinemann Educational Books.

Seashore, C. E. (1938). *The Psychology of Music.* New York: McGraw-Hill.

Seddon, F. A. (2005). Modes of Communcation During Jazz Improvisation. *British Journal of Music Education, 22*(1), 47–61.

Semjen, A., Schulze, H. H. & Vorberg, D. (2000). Timing Precision in Continuation and Synchronization Tapping. *Psychological Research, 63*(2), 137-147.

Shaffer, L.H., & Todd, N.P.M. (1987). The Interpretative Component in Musical Performance. In A. Gabrielsson (Ed.), *Action and Perception in Rhythm and Music, Vol. 55* (pp. 139–152). Stockholm, Sweden: Royal Swedish Academy of Music.

Sloboda, J. A. (1985). *The Musical Mind.* Oxford: Oxford University Press.

Sloboda, J. A. (1988). *Generative Processes in Music: The psychology of performance, improvisation and composition.* Oxford, Clarendon Press.

Smith, A. (1776). An Inquiry into the Nature and Causes of the Wealth of Nations. In E. Cannan (Ed.), *Library of Economics and Liberty*, (1904). Retrieved from: http://www.econlib.org/library/Smith/smWN.html, 2/11/2011.

Snyder, B. (2000). *Music and Memory: An introduction.* Cambridge: The MIT Press.

Snyder, J. S. & Krumhansl, C. L. (2001).Tapping to Ragtime: Cues to Pulse Finding. *Music Perception, 18*(4), 455-489.

Spencer, H. (1862). *First Principles.* London: Williams and Norgate.

Stern, D. N. (1985). *The Interpersonal World of the Infant: A view from psychoanalysis and developmental psychology.* New York: Basic Books.

Stern, D. N. (1989). Developmental Prerequisites for the Sense of a Narrated Self. In A.M. Cooper, O.F. Kernberg & E.S. Person (Eds.), *Psychoanalysis: Toward the second century* (pp. 168-178). New Haven, CT: Yale University Press.

Stern, D. N. (2000). Putting Time Back Into Our Considerations of Experience: A micro-diachronic view. *Infant Mental Health Journal, 21*(1-2), 21-28.

Stern, D. N. (2004). The Present Moment as a Critical Moment. *Negotiation Journal, 20*(2), 365-372.

Stern, D. N., Beebe, B., Jaffe, J., & Bennett, S. L. (1977). The Infant's Stimulus World During Social Interaction: A study of caregiver behaviours with particular reference to repetition and timing. In H. R. Schaeffer (Ed.), *Studies in Mother-Infant Interaction* (pp. 177-202). London: Academic Press.

Stetson, R. (1905). A Motor Theory of Rhythm and Discrete Succession. *Psychological Review, 12*, 250-350.

Stephens, G. J., Silbert, L. J. & Hasson, U. (2010). Speaker–Listener Neural Coupling Underlies Successful Communication. *Proceedings of the National Academy of Sciences, 107*(32), 14425-14430.

Stewart, M. (1987). The Feel Factor: Music with Soul. *Electronic Musician, October,* 57- 65.

Stobart, H. & Cross, I. (2000). The Andean Anacrusis? Rhythmic structure and perception in Easter songs of Northern Potosí, Bolivia. *British Journal of Ethnmusicology, 9*(2), 63-94.

Storr, A. (1992). *Music and the Mind.* New York: Free Press.

Sundberg, J. (1988). Computer Synthesis of Music Performance. In J. A. Sloboda (Ed.), *Generative Processes in Music* (pp. 52-69). Oxford, Clarendon Press.

Sundberg, J., Friberg, A. & Bresin, R. (2003). Attempts to Reproduce a Pianist's Expressive Timing with Director Musices Performance Rules. *Journal of New Music Research, 32(*3), 317-325.

Tannen, D. (1989). *Talking Voices: Repetition, dialogue, and imagery in conversational* *discourse.* Cambridge: Cambridge University Press.

Thackray, R. (1969). *Rhythmic Abilities and their Measurement.* Unpublished Doctoral Thesis, University of Reading.

Thaut, M. H. (2003). Neural Basis of Rhythmic Timing Networks in the Human Brain. *Annals of the New York Academy of Sciences, 999*, 364-373.

Thaut, M. H. & Miller, R. A. (1994). Multiple Synchronisation Strategies in Tracking of Rhythmic Auditory Stimulation. *Proceedings of the Society of Neuroscience, 146*, 11.

Thaut, M. H., Stephan, K. M., Wunderlich, G., Schicks, W., Tellmann, L., Herzog, H., McIntosh, G. C., Seitz, R. J. & Hömberg, V. (2009). Distinct cortico-cerebellar activations in rhythmic auditory motor synchronization, *Cortex, 45*(1), 44-53.

Thelen, E. & Smith, L. (1994). *A Dynamics System Approach to the Development of Cognition and Action.* Cambridge, MA: MIT Press.

Thorpe L. A. & Trehub, S. E. (1989). Duration Illusion and Auditory Grouping in Infancy. *Developmental Psychology, 25*, 122-127.

Tickle-Degnen, L. & Rosenthal, R. (1990). The Nature of Rapport and Its Nonverbal Correlates. *Psychological Inquiry, 1*(4), 285-93.

Todd, N. P. (1985). A Model of Expressive Timing in Tonal Music. *Music Perception, 3,* 33-58.

Todd, N. P. (1989). Towards a Cognitive Theory of Expression: The Performance and Perception of Rubato. *Computer Music Research, 4*, 405-416.

Todd, N. P. (1994). The Auditory "Primary Sketch": A Mutliscale model of rhythmic grouping. *Journal of New Music Research, 23*, 25-70.

Tomasello, M., Carpenter, M., Cal, J., Behne, T. & Moll, H. (2005). Understanding and Sharing Intentions: The origins of cultural cognition. *Behavioural and Brain Sciences, 28*(5), 675-691.

Torre, V., Ashmore, J. F., Lamb, T. D. & Menini, A. (1995). Transduction and Adaptation in Sensory Receptor Cells. *The Journal of Neuroscience: The Official Journal of the Society For Neuroscience*, *15*, 7757-7768.

Trainor, L. J. & Adams, B. (2000). Infants' and Adults' Use of Duration and Intensity Cues in the Segmentation of Tone Patterns. *Perception & Psychophysics, 62*(2), 333-340.

Trainor, L. J., Gao, X., Lei, J., Lehtovaara, K. & Harris, L. R. (2009). The Primal Role of the Vestibular System in Determining Musical Rhythm. *Cortex, 45*(1), 35-43.

Trehub, S. E. (1990). The Perception of Musical Patterns by Human Infants: The provision of similar patterns by their parents. In M. A. Berkley & W. C. Stebbins (Eds.), *Comparative Perception, Vol. 1: Mechanisms* (pp. 429-459). New York: Wiley.

Trehub, S. E. & Hannon, E. E. (2009). Conventional Rhythms Enhance Infants' and Adults'

Perception of Musical Patterns. *Cortex, 45*(1), 110-118.

Trevarthen, C. (1974). Conversations with a 2-month-old. *New Scientist,* 230-235.

Trevarthen, C. (1979). Communication and Cooperation in Early Infancy. A description of primary intersubjectivity. In M. Bullowa (Ed.), *Before Speech: The beginning of human communication*, (pp. 321-347). London, Cambridge University Press.

Trevarthen, C. (1999). Musicality and the Intrinsic Motive Pulse: Evidence from human psychobiology and infant communication. *Musicæ Scientiæ, Special Issue: Rhythm, musical narrative, and the origins of human communication, (1999-2000),* 157-213.

Trevarthen, C. (2001). Intrinsic Motives for Companionship in Understanding: Their origin, development and significance for infant mental health. *Infant Mental Health Journal, 22*(1-2), 95-131.

Trevarthen, C. (2009). Human Chronobiology: On the source and functions of « musicality ». In R. Haas & V. Brandes (Eds.), *Music That Works: Contributions of biology, neurophysiology, psychology, sociology, medicine and musicology* (pp. 221-266). Spinger-Verlag : Wien.

Trevarthen C. (2011). Born For Art, and the Joyful Companionship of Fiction. In D. Narvaez, J. Panksepp, A. Schore & T. Gleason (Eds.), *Human Nature, Early Experience and the Environment of Evolutionary Adaptedness.* Oxford: Oxford University Press.

Trevarthen, C. & Aitken, K. J. (1994). Brain Development, Infant Communication and Empathy Disorders: Intrinsic factors in child mental health. *Development & Psychopathology, 6,* 597-633.

Trevarthen, C. & Gratier, M. (2005). Voix et Musicalité: Nature, émotion, relations et culture. In M.-F. Castarède & G. Konopczynski (Eds.), *Au Commencement Etait la Voix* (pp. 105-116). Ramonville Saint-Agne: Erès.

Trevarthen, C. & Malloch, S. (2002). Musicality and Music Before three: Human vitality and invention shared with pride. *Zero-to-Three, 23*(1), 1-22.

Tse, P. U., Rivest, J., Intriligator, J. & Cavanagh, P. (2004). Attention and the Subjective Expansion of Time. *Perception & Psychophysics, 66*, 1171–1189.

Turner, E. O. (1938). Tempo Variation: With Examples from Elgar. *Music and Letters, 19*(3), 308-323.

Turner, F. & Ioannides, A. A. (2009). Brain, Music and Musicality: Inferences from Neuroimaging. In S. Malloch and C. Trevarthen (Eds.), *Communicative Musicality: Exploring the basis of human companionship.* (pp. 147-182). Oxford: Oxford University Press.

Turner, F. & Pöppel, E. (1983). The Neural Lyre. *Poetry, 142*(5), 277-309.

Van Noorden, L. & Moelants, D. (2006). Guest Editorial: 'Special Issue: Papers from the 10th Rhythm Perception and Production Workshop'. *Music Perception*, *24*(2), 123-124.

Varela, F., Thompson, E. & Rosch, E. (1991). *The Embodied Mind: Cognitive science and* *human experience.* Cambridge, MA: MIT Press.

Vernon, L. N. (1937). Synchronization of chords in artistic piano music. In C. E. Seashore (Ed.), *Objective analysis of musical performance* (pp. 306-345). University of Iowa Studies in the Psychology of Music, Vol. 4. Iowa City: University of Iowa Press.

Vygotsky, L. S. (1978). *Mind in Society: The development of higher psychological processes.* Cambridge, MA.: Harvard University Press.

Walker, A. (1994). *A Conversational-Based Framework for Musical Improvisation.* Unpublished Doctoral Dissertation, University of Urbana: Illinois.

Wallin, J. E. W. (1911). Experimental Studies of Rhythm and Time. I. Qualitative limens or grades of rhythm, and the difference limen in the perception of time. *Psychological Review, 18*, 100–131.

Walther, J. B. & Tidwell, L. C. (1995). Nonverbal Cues in Computer-Mediated Communication and the Effect of Chronemics on Relational Communication. *Journal of Organizational Computing, 5,* 355–378.

Wanderley, M. M. (2002). Quantitative Analysis of Non-Obvious Performer Gestures. In I. Wachsmuth & T. Sowa (Eds.), *Gesture and Sign Language in Human-Computer Interaction* (pp. 241-253). Berlin: Springer.

Wanderley, M. M., Vines, B. W., Middleton, N., McKay, C. & Hatch, W. (2005). The Musical Significance of Clarinetists' Ancillary Gestures: An exploration of the field. *Journal of New Music Research, 34*(1), 97-113.

Warner, R., Malloy, D., Schneider, K., Knoth, R. & Wilder, B. (1987). Rhythmic Organization of Social Interaction and Observer Ratings of Positive Affect and Involvement. *Journal of Nonverbal Behavior, 11*(2), 57-74.

Weeks, P. A. D. (1990). Musical Time as a Practical Accomplishment: A change in tempo. *Human Studies, 13*(4), 323-59.

Whittman, M. & Pöppel, E. (1999). Temporal Mechanisms of the Brain as Fundamentals of Communication with Special Reference to Music Perception and Performance. *Musicæ Scientiæ, Special Issue: Rhythm, musical narrative, and the origins of human communication, (1999-2000),* 13-28.

Williamon, A. & Davidson, J. W. (2002). Exploring Co-Performer Communication. *Musicae Scientiae, VI*(1), 53-72.

Wing, A. M. & Kristofferson, A. B. (1973). The Timing of Interresponse Intervals. *Perception & Psychophysics, 13*(3), 455-460.

Winkler, I., Haden, G. P., Ladinig, O., Sziller, I. & Honing, H. (2009). Newborn Infants Detect the Beat in Music. *Proceedings of the National Academy of Sciences, 106*(7), 2468-2471.

Weber, Carl Maria Friedrich Ernst von (1824). Correspondance. Quoted in B. Bruck, (1929) *Wandlungen des Begriffes Tempo Rubato* (Dissertation). Berlin: Druck von P. Funk.

Woodrow, H. (1932). The Effect of Rate of Sequence Upon the Accuracy of Synchronization. *Journal of Experimental Psychology*, 15, 357-379.

Yamada, N. (1995). Nature of Variability in Rhythmical Movement. *Human Movement Science, 14*, 371-384.

Zbikowski, L. M. (2004). Modelling the Groove: Conceptual Structure and Popular Music. *Journal of the Royal Musical Association, 129*(2), 272-297.

Zentner, M. & Eerola, T. (2010). Rhythmic Engagement with Music in Infancy. *Proceedings of the National Academy of Sciences, 107*(13), 5768-5773.

Numéro | | | |

Expérience Musicale

Lundi 29 Mars 2010

Rebecca Evans – ATER, Doctorante, Psychomuse

Etude A :

Quel extrait préférez-vous ?	1	2	3
Quel extrait préférez-vous le moins ?	1	2	3

Pourquoi ? ____

____

____

Etude B :

Extrait 1 :

Version A :

1. Indiquez à quel point vous **aimez** cette version :	**1** pas du tout	-	**2** pas vraiment	-	**3** ni plus ni moins	-	**4** un peu	-	**5** beaucoup
2. Indiquez à quel point vous sentez que cette version est **naturelle** :	**1** pas du tout	-	**2** pas vraiment	-	**3** ni plus ni moins	-	**4** un peu	-	**5** beaucoup
3. Indiquez à quel point vous pensez que les musiciens sont **calés temporellement** :	**1** pas du tout	-	**2** pas vraiment	-	**3** ni plus ni moins	-	**4** un peu	-	**5** beaucoup

Version B :

1. Indiquez à quel point vous **aimez** cette version :	**1** pas du tout	-	**2** pas vraiment	-	**3** ni plus ni moins	-	**4** un peu	-	**5** beaucoup
2. Indiquez à quel point vous sentez que cette version est **naturelle** :	**1** pas du tout	-	**2** pas vraiment	-	**3** ni plus ni moins	-	**4** un peu	-	**5** beaucoup
3. Indiquez à quel point vous pensez que les musiciens sont **calés temporellement** :	**1** pas du tout	-	**2** pas vraiment	-	**3** ni plus ni moins	-	**4** un peu	-	**5** beaucoup

Version C :

1. Indiquez à quel point vous **aimez** cette version :	**1** pas du tout	-	**2** pas vraiment	-	**3** ni plus ni moins	-	**4** un peu	-	**5** beaucoup
2. Indiquez à quel point vous sentez que cette version est **naturelle** :	**1** pas du tout	-	**2** pas vraiment	-	**3** ni plus ni moins	-	**4** un peu	-	**5** beaucoup

3. Indiquez à quel point vous pensez que les musiciens sont **calés temporellement** :
1 - **2** - **3** - **4** - **5**
pas du tout / pas vraiment / ni plus ni moins / un peu / beaucoup

Version D :

1. Indiquez à quel point vous **aimez** cette version :
1 - **2** - **3** - **4** - **5**
pas du tout / pas vraiment / ni plus ni moins / un peu / beaucoup

2. Indiquez à quel point vous sentez que cette version est **naturelle** :
1 - **2** - **3** - **4** - **5**
pas du tout / pas vraiment / ni plus ni moins / un peu / beaucoup

3. Indiquez à quel point vous pensez que les musiciens sont **calés temporellement** :
1 - **2** - **3** - **4** - **5**
pas du tout / pas vraiment / ni plus ni moins / un peu / beaucoup

Extrait 2 :

Version A :

1. Indiquez à quel point vous **aimez** cette version :
1 - **2** - **3** - **4** - **5**
pas du tout / pas vraiment / ni plus ni moins / un peu / beaucoup

2. Indiquez à quel point vous sentez que cette version est **naturelle** :
1 - **2** - **3** - **4** - **5**
pas du tout / pas vraiment / ni plus ni moins / un peu / beaucoup

3. Indiquez à quel point vous pensez que les musiciens sont **calés temporellement** :
1 - **2** - **3** - **4** - **5**
pas du tout / pas vraiment / ni plus ni moins / un peu / beaucoup

Version B :

1. Indiquez à quel point vous **aimez** cette version :
1 - **2** - **3** - **4** - **5**
pas du tout / pas vraiment / ni plus ni moins / un peu / beaucoup

2. Indiquez à quel point vous sentez que cette version est **naturelle** :
1 - **2** - **3** - **4** - **5**
pas du tout / pas vraiment / ni plus ni moins / un peu / beaucoup

3. Indiquez à quel point vous pensez que les musiciens sont **calés temporellement** :
1 - **2** - **3** - **4** - **5**
pas du tout / pas vraiment / ni plus ni moins / un peu / beaucoup

Version C :

1. Indiquez à quel point vous **aimez** cette version :
1 - **2** - **3** - **4** - **5**
pas du tout / pas vraiment / ni plus ni moins / un peu / beaucoup

2. Indiquez à quel point vous sentez que cette version est **naturelle** :
1 - **2** - **3** - **4** - **5**
pas du tout / pas vraiment / ni plus ni moins / un peu / beaucoup

3. Indiquez à quel point vous pensez que les musiciens sont **calés temporellement** :
1 - **2** - **3** - **4** - **5**
pas du tout / pas vraiment / ni plus ni moins / un peu / beaucoup

Version D :

1. Indiquez à quel point vous **aimez** cette version :
1 - **2** - **3** - **4** - **5**
pas du tout / pas vraiment / ni plus ni moins / un peu / beaucoup

2. Indiquez à quel point vous sentez que cette version est **naturelle** :
1 pas du tout - **2** pas vraiment - **3** ni plus ni moins - **4** un peu - **5** beaucoup

3. Indiquez à quel point vous pensez que les musiciens sont **calés temporellement** :
1 pas du tout - **2** pas vraiment - **3** ni plus ni moins - **4** un peu - **5** beaucoup

Extrait 3 :

Version A :

1. Indiquez à quel point vous **aimez** cette version :
1 pas du tout - **2** pas vraiment - **3** ni plus ni moins - **4** un peu - **5** beaucoup

2. Indiquez à quel point vous sentez que cette version est **naturelle** :
1 pas du tout - **2** pas vraiment - **3** ni plus ni moins - **4** un peu - **5** beaucoup

3. Indiquez à quel point vous pensez que les musiciens sont **calés temporellement** :
1 pas du tout - **2** pas vraiment - **3** ni plus ni moins - **4** un peu - **5** beaucoup

Version B :

1. Indiquez à quel point vous **aimez** cette version :
1 pas du tout - **2** pas vraiment - **3** ni plus ni moins - **4** un peu - **5** beaucoup

2. Indiquez à quel point vous sentez que cette version est **naturelle** :
1 pas du tout - **2** pas vraiment - **3** ni plus ni moins - **4** un peu - **5** beaucoup

3. Indiquez à quel point vous pensez que les musiciens sont **calés temporellement** :
1 pas du tout - **2** pas vraiment - **3** ni plus ni moins - **4** un peu - **5** beaucoup

Version C :

1. Indiquez à quel point vous **aimez** cette version :
1 pas du tout - **2** pas vraiment - **3** ni plus ni moins - **4** un peu - **5** beaucoup

2. Indiquez à quel point vous sentez que cette version est **naturelle** :
1 pas du tout - **2** pas vraiment - **3** ni plus ni moins - **4** un peu - **5** beaucoup

3. Indiquez à quel point vous pensez que les musiciens sont **calés temporellement** :
1 pas du tout - **2** pas vraiment - **3** ni plus ni moins - **4** un peu - **5** beaucoup

Version D :

1. Indiquez à quel point vous **aimez** cette version :
1 pas du tout - **2** pas vraiment - **3** ni plus ni moins - **4** un peu - **5** beaucoup

2. Indiquez à quel point vous sentez que cette version est **naturelle** :
1 pas du tout - **2** pas vraiment - **3** ni plus ni moins - **4** un peu - **5** beaucoup

3. Indiquez à quel point vous pensez que les musiciens sont **calés temporellement** :
1 pas du tout - **2** pas vraiment - **3** ni plus ni moins - **4** un peu - **5** beaucoup

Extrait 4 :

Version A :

1. Indiquez à quel point vous **aimez** cette version :	**1** pas du tout	**-**	**2** pas vraiment	**-**	**3** ni plus ni moins	**-**	**4** un peu	**-**	**5** beaucoup
2. Indiquez à quel point vous sentez que cette version est **naturelle** :	**1** pas du tout	**-**	**2** pas vraiment	**-**	**3** ni plus ni moins	**-**	**4** un peu	**-**	**5** beaucoup
3. Indiquez à quel point vous pensez que les musiciens sont **calés temporellement** :	**1** pas du tout	**-**	**2** pas vraiment	**-**	**3** ni plus ni moins	**-**	**4** un peu	**-**	**5** beaucoup

Version B :

1. Indiquez à quel point vous **aimez** cette version :	**1** pas du tout	**-**	**2** pas vraiment	**-**	**3** ni plus ni moins	**-**	**4** un peu	**-**	**5** beaucoup
2. Indiquez à quel point vous sentez que cette version est **naturelle** :	**1** pas du tout	**-**	**2** pas vraiment	**-**	**3** ni plus ni moins	**-**	**4** un peu	**-**	**5** beaucoup
3. Indiquez à quel point vous pensez que les musiciens sont **calés temporellement** :	**1** pas du tout	**-**	**2** pas vraiment	**-**	**3** ni plus ni moins	**-**	**4** un peu	**-**	**5** beaucoup

Version C :

1. Indiquez à quel point vous **aimez** cette version :	**1** pas du tout	**-**	**2** pas vraiment	**-**	**3** ni plus ni moins	**-**	**4** un peu	**-**	**5** beaucoup
2. Indiquez à quel point vous sentez que cette version est **naturelle** :	**1** pas du tout	**-**	**2** pas vraiment	**-**	**3** ni plus ni moins	**-**	**4** un peu	**-**	**5** beaucoup
3. Indiquez à quel point vous pensez que les musiciens sont **calés temporellement** :	**1** pas du tout	**-**	**2** pas vraiment	**-**	**3** ni plus ni moins	**-**	**4** un peu	**-**	**5** beaucoup

Version D :

1. Indiquez à quel point vous **aimez** cette version :	**1** pas du tout	**-**	**2** pas vraiment	**-**	**3** ni plus ni moins	**-**	**4** un peu	**-**	**5** beaucoup
2. Indiquez à quel point vous sentez que cette version est **naturelle** :	**1** pas du tout	**-**	**2** pas vraiment	**-**	**3** ni plus ni moins	**-**	**4** un peu	**-**	**5** beaucoup
3. Indiquez à quel point vous pensez que les musiciens sont **calés temporellement** :	**1** pas du tout	**-**	**2** pas vraiment	**-**	**3** ni plus ni moins	**-**	**4** un peu	**-**	**5** beaucoup

Etude C :

A partir de quelle version considérez-vous que les musiciens ne sont plus calés dans le temps, c'est à dire ne sont plus en synchronie ou en phase l'un avec l'autre ? Entourez vos réponses.

Extrait 1 :	A	B	C	D	E	F
Extrait 2 :	A	B	C	D	E	F

Extrait 3 : A B C D E F

Extrait 4 : A B C D E F

Questionnaire

Age :

Sexe : Homme ☐ Femme ☐

Jouez-vous ou avez-vous déjà joué d'un instrument de musique ? Oui ☐ Non ☐

Si oui lequel ? …………………………………………….

Si oui depuis combien de temps pratiquez-vous cet instrument ou pendant combien de temps avez-vous pratiqué cet instrument ? ………………………………………

Avez-vous déjà pratiqué le solfège ? Oui ☐ Non ☐

Si oui pendant combien de temps ? ……………………………………

Quelles sont vos préférences de genre de musique ? …………………………………………………………………………

Quelle est la durée de votre écoute de musique par semaine ?

0 heure☐ 1-5 heures ☐ 5-10 heures☐ 10-15 heures ☐ 15 heures+ ☐

Que veut dire pour vous : être ensemble dans le temps dans la musique ? ou que deux musiciens soient ensemble dans le temps ?

………

………

………

………

………

………

Ces exercices étaient-ils difficiles pour vous ?

Oui ☐ Non ☐

Si oui lesquels :

Etude A ☐ Etude B ☐ Etude C ☐

Merci pour votre participation à cette expérience.