

TIME: TIMING AND SOUND IN MUSICAL MICRO-RHYTHM

1. THE RESEARCH PROJECT: BACKGROUND, STATEMENT OF PROBLEM, HYPOTHESES, AND OBJECTIVES

Introduction. When does a beat actually happen in time? This might seem like an easy question to answer. When we zoom in on an actual piece of music, however, we discover that at the micro level, even the most percussive of sounds has a certain duration and shape in time. What part of that sound constitutes the beat's temporal position, and how does this perception or judgment depend upon a listener's music-cultural background? The answers to these simple questions have wide-ranging implications for understanding temporal relationships in music performance and perception, as well as auditory perception in general. Ultimately, they also engage with the role of cultural background and/or training in auditory perception.

The basic hypothesis of this project is that *sound-related aspects, such as temporal shape, intensity, and timbre, influence our perception of temporal relationships in music at the micro level*, and, moreover, that *this co-varies with music-cultural training and background*. This means that when listening to a musical waveform such as that depicted to the left in fig. 1, for example, there is no single universal way to perceive that sound. The part of the sound that constitutes its perceived timing (what in linguistics is called the perceptual center or P-center) may vary, for example—one listener might hear the beginning of the sound (the onset) as its primary temporal location, whereas another might rely on the loudest part of the sound (the peak in the middle). Moreover, if the musical event should consist of two waveforms from different sources that are heard as one (fig. 1, right), which is very common when several instruments sound at the same time, it might vary as to which one is decisive for *when this compound* musical event is perceived as taking place. These potential variations can be thought to follow patterns of differences in cultural background and training. A musician or listener belonging to a more “laid-back” timing tradition can be drawn to the later position, whereas a listener accustomed to music with very tight or accurate timing might use the earlier position, or the start of the event. Put differently, in this project we hypothesize that musical-cultural experiences are *perceptually formative*—that they make an imprint not only on how we understand and assess sensory information but also on perceptual mechanisms in the individual at the most basic level.

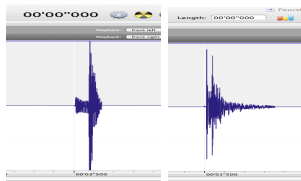


Figure 1. Waveforms (amplitude/time) of a simple sound with a late peak (left) and a compound sound (right).

We have singled out four musical genres/genre cultures (see also table 1 below) in which rhythm is variably constituted as a key aesthetic marker: jazz, electronic dance music (EDM), contemporary R&B/hip-hop, and traditional Scandinavian fiddle music. As is evident from the music, as well as the discursive valorization, the relationship between their temporal and sound-related features varies at the micro-rhythmic level. This makes them particularly suited to comparisons, which allows us to check our findings and interpretations across different but related forms of music.

Research questions and objectives. The overall research question of the project is: *How do features of sound interact with timing at the micro level of auditory perception?* More specifically, we ask, first: How do sound-related features influence temporal placement in music, as well as auditory perception in general? Our research also produces an acute awareness of *the role of cultural context and cultural variation for auditory perception*. Secondly, then, we ask: To what extent is the perception of temporal relationships at the micro level of music dependent on musical-cultural background and training? For this study, “timing” refers to the placement of a rhythmic event in time, whereas “sound” refers to timbre and intensity, understood as both these global features themselves and their dynamic evolution over time. The physical correlate to perceived intensity is sound pressure level (and likewise, the inner dynamics of a sound can be approached as the amplitude envelope of intensity). The physical correlate to perceived timbre is less straightforward and varies with the sound in question (Grey 1977; Lakatos 2000). Even though the different aspects of sound–timing interactions can be difficult to distinguish at a phenomenological level, they can still be measured in the physical signal and analyzed after the fact.

We intend to answer these questions through an in-depth study of musical micro-rhythm. Music

presents a unique opportunity to study the interaction of sound and timing at the micro level of hearing, since, as an art form, music is intended to engage our senses and often probes the very margins of perception. Studies concerning the interaction of sound and timing at the micro level of music have been completely absent from earlier research into rhythm in music (see state-of-the-art section below). Through the present project, we expect to gain new empirical and theoretical knowledge about not only the four musical genres in question but also the interaction between temporal and sound-related features in auditory perception in general, as well as the role of cultural variation in this regard.

Impact. The research questions for the present project, which concern the relationship between temporal and sound-related features of musical events across musical cultures, might at first seem rather particular. Yet they touch upon important and wide-ranging topics that extend beyond the realm of music performance and music perception. First, they concern the ways in which *sound-related features of an auditory event impact the perception of its temporal position*, and the *de facto* fluidity of boundaries between sound and timing at the micro level of auditory perception (Hartmann 1995). Unlike visual perception, auditory perception is a severely under-researched area, even though it is crucial to understand the basic perceptual principles through which we as human beings gather auditory information. We know, for example, that our perceptive abilities regarding sound and timing provide us with important knowledge about other human beings and our environments (consider, for example, our sensitivity to timing in verbal communication, or our ability to describe the features of a given space based upon how it reflects sound).

Second, the design of the present research project concerns *the role of cultural context and cultural variation for perception*. By looking at the extent to which the perception of temporal relationships at the micro level of music depends upon training and musical-cultural background, we wade into the debate regarding the relationship between perception and culture, and the question of primacy therein. This is a very current debate that has been reactivated by neuroscientific research that has established that brain structures are not a consistent given. Instead, the particular structure of each human brain, in the sense of its unique pattern of neural connections, adapts to its environment from day one. The capacities of a musician's brain can thus be considered an imprint of his or her total and cumulative environmental stimulation and experience (Münste et al 2002).

Through this project, we are using rhythm, a fundamental and universal aspect of musical expression, as a test case in this larger debate about culture and perception. The proposed project therefore has the potential to impact all of the scholarly fields that are engaged in research into auditory perception in general, such as psychoacoustics and those areas of psychology dealing with music, language, and auditory perception. In addition, through its systematic research into an entirely new dimension (the sound) of musical rhythm, it might supply new, even groundbreaking knowledge about micro-level relationships in music in general, and musical rhythm in particular—knowledge of fundamental relevance to musicology, ethnomusicology, music theory, music performance, and music psychology. The findings will also attract scholars in the growing field of “music information retrieval”—in particular, those groups working with search engines for music. They will also be relevant to research into speech recognition.

The most important and wide-ranging impact of the project, however, lies in its potential to provide fresh insight into the role of cultural variation and cultural context in auditory perception, linking the study of music to those ongoing debates on the relationship between cultural variation and neuroplasticity in neuroscience, cognitive psychology, and linguistics.

Research into Sound–Timing Relationships in Music: State of the Art. Traditionally, Western musicological research into rhythm has contented itself with a notion of rhythmic structure that is derived entirely from those aspects of it that can be captured by music notation (Cooper and Meyer 1963; Lerdahl and Jackendoff 1996). It has generally ignored issues of micro-rhythm, here understood as the overall rhythmic shaping of musical events at the micro level, encompassing *timing* (that is, when a rhythmic event starts and ends—early, late, or on the beat), *duration* (whether the sound is short or long), *shape* (how the energy of the sound unfolds over time—for example, whether the attack is sudden or soft), *timbre* (the sound color), and *intensity* (whether the sound is loud or light). Over the past thirty years, studies of strictly temporal aspects of micro-rhythm (timing and duration) in both classical and groove-based musics have increased in number and scope (see, for example, Alén 1995; Bengtsson and Gabrielsson 1983; Bilmes 1993; Butterfield 2010; Chor 2010; Clarke 1985, 1989; Danielsen 2006, 2010a, 2010b; Desain and Honing 1989; Friberg and Sundström 2002; Iyer 2002; Johansson 2010a, 2010b; Kvifte 2004, 2007; Polak 2010; Polak and London 2014; Prögler 1995). Most of these scholars have approached rhythmic events as relationships between points in time by investigating attack points, durations, and/or Inter-Onset-Intervals (IOI). The

reference structures that have formed the basis for identifying micro-timing—that is, for determining whether a beat is early or late—have for the most part been conceptualized as a metric grid consisting of series of isochronous points in time. Up until very recently, then, micro-rhythm was treated mainly as a temporal phenomenon and measured as deviations from a static metric grid.

A first challenge to this traditional approach came from research into orally transmitted musical traditions, such as Scandinavian fiddle music, African American dance music, and West African drumming. In these cases, a reduction of the rhythmic structure to a constellation of virtual points in a static, isochronous time grid did not work very well. The present project's PI and others proposed a revised notion of rhythmic/metric structure to better accommodate this material (see, for example, Danielsen 2006, 2010b; Johansson 2010b; Kvifte 2007; Polak 2010; Polak and London 2014). This challenged the traditional equation of the relationship between structure and expression in music with the relationship between notation and performance by incorporating systematic patterns of micro-timing into the concept of the music's rhythmic structure, thereby opening up for non-isochronous meter and extended beats (that is, an unequal division of the bar, and beats of different lengths).

The next step in this effort is to incorporate systematic micro-level patterns of *sound*—that is, intensity, timbre, and shape—and to address the interaction between sound and timing at the micro level, and this is exactly what this project seeks to achieve. While several works within the disciplines of musicology, music psychology, and ethnomusicology touch upon the influence of sound on timing (see, for example, Danielsen 2006, 2010a, 2012, 2015; Goebel and Parncutt 2002; Hove et al. 2007; Johansson 2010a) or timing on sound (Goebel 2001; Palmer 1996; Repp 1996; Sloboda 1983), no research has so far addressed this interaction in full. Generally, scholars have excluded aspects of sound from studies of micro-timing and overlooked sound's impact on micro-rhythmic relationships. A few pioneering works (Fraise 1982; Woodrow 1909), as well as some more recent empirical research (Povel and Okkerman 1981; Tekman 1995, 1997, 2001, 2002; Windsor 1993), have addressed the relationship between perceived dynamic accents (increases in intensity) and perceived duration. Certain studies of music performance have also discovered a close relationship between dynamic accents and duration, finding, for example, that accented beats are lengthened in performance or tied to the following note (see, for example, Clarke 1988; Dahl 2000, 2004; Drake and Palmer 1993; Gabrielsson 1999; Waadeland 2003, 2006). This area of research, however, examines only one aspect of sound (sound intensity or dynamics) and one aspect of timing (duration). Apart from one study by Naveda et al (2010), other aspects, such as timbre or temporal shape (how the sound evolves over time), have been neglected, probably because most of the aforementioned research has relied upon manufactured sounds—clicks or tones that demonstrate no development over time and thus present no challenge as to when they actually start and end. In studies using real music, the onset of a note, tone, or beat has been regarded as equivalent to its temporal position (see, for example, Butterfield 2010). However, although this is how temporal position is conceptualized in many contexts, such as music notation, most music analysis, and the visualization of music in music software, it does not adequately represent how it is perceived. One study by Wright (2008), for example, addressing the flexibility of the perceived center (the P-center) of various resynthesized orchestral sounds, found that the onset of a sound is *rarely* the perceived center. In short, experimental research into the interaction of sound and timing using *real* sounds with different timbres, unique dynamic profiles, and distinctive shapes is long overdue. It is time to move beyond clicks to real music in experimental research into musical rhythm.

Addressing the impact of micro-level sound-related features on timing is obviously relevant to the disciplines involved in the study of music. A related need, however, is that such investigations of micro-level features of music are framed by, and discussed as, part of the larger field of the cultural study of music. Following Clayton et al. (2013), this means that investigations zooming in on the moment of performance and perception have to be reckoned against an abiding concern and interest in musical discourses and shared patterns of meaning-making, as well as disputes over such meanings (Toynbee 2000). Accordingly, musical genres should not be considered static systems of classification but instead dynamic formations that undergo constant renegotiation.

Comparative research into different musical genres' various forms of valorization, aesthetics, and ways of hearing and perceiving such micro-level features might also have wide-ranging consequences for the understanding of auditory perception in general, because it will shed light on the ways in which the experience of relationships between sound and timing are influenced by musical-cultural background and training. Neuroscientific research indicates that differences in musical cognitive skills between musicians and non-musicians can be traced to differences in both brain structure and function (for a review of the literature, see Vuust et al. 2012). Investigating more specific differences between musicians and non-

musicians in auditory processing, several studies using the mismatch negativity (MMN) paradigm show that musicians' brains process auditory information differently depending on their practice, and, moreover, that the MMN is sensitive to acoustic features specific to instrumental practice and the training typical of different musical genres (Brattico et al. 2009, 2013; Vuust et al. 2012). There is, in other words, emerging evidence for a more *specific* music-derived neuroplasticity—that is, not only music in general but also experiences with *particular instruments, styles, and genres* of music seem to shape auditory processing in the brains of musicians at a pre-attentive level. This lends support to the main hypothesis of this project: sound-timing interactions might be perceived differently according to the musical-cultural background and training of the listener. What is heard as two different musical events in one music culture might, for example, be heard as one entity in another, thanks to a larger tolerance for beats with extension in time (Danielsen 2010a, 2012, 2015).

Summing up, then, the impact of sound-related features on perceived timing, and cultural variations in the experience of such micro-rhythmic relationships, needs to be addressed.

2. THE PROJECT PLAN: METHODS, WORK PACKAGES, PROJECT MANAGEMENT, ORGANIZATION, AND COOPERATION

This project employs a truly multidisciplinary approach that combines interpretive traditions from the humanities with systematic experimental designs from the sciences in a unique way. Accordingly, we will study both the discourse surrounding our selected musical genres and the musical expressions themselves, through both music analysis and interpretation. In addition, we will single out some central hypotheses produced by this interpretative work for experimental testing. We will focus on four musical genres/genre cultures (see table 1) in which rhythm is variably constituted as a key aesthetic marker. This means that we will gain, in addition to the comparative insights, valuable knowledge about four different genres. Moreover, because two are based on traditional musicianship, and two rely mainly on computer-based modes of production, we can compare and contrast the impact of sound–timing interactions according to this parameter as well.

Table 1. Overview of styles/subcultures and their respective micro-rhythmic features (in parentheses).

<i>Traditional musicianship</i> (“played”)	Jazz (accuracy in timing, but not on the grid)	Scandinavian fiddle music (extremely flexible timing, timing governed by melodic structure)
<i>Computer-based musicianship</i>	EDM (timing on the grid, focus on features of sound)	Contemporary R&B/hip-hop (laid-back timing, vagueness regarding temporal positions, focus on features of sound)

The project's innovative integration of humanistic approaches (such as qualitative interviews, music analysis, and aesthetic interpretation) and systematic experimental designs derived from the sciences represents the tapping of an enormous potential in music research. First, it allows for the pursuit and development of particularly interesting paths of investigation that are exposed via the interpretive exploration in carefully designed experimental work. Second, it brings together perspectives and knowledge from traditions and approaches that are typically disparate. Third, the combination of a narrowly focused research agenda and a multidisciplinary approach allows for a special penetration into the subject matter at hand. Our aim is to shed light on the main research questions from the following different but complementary angles:

- A. Qualitative interviews
- B. Music analysis and aesthetic interpretation
- C. Experimental studies
- D. Genre analysis
- E. Cultural comparison

The project encompasses all of the disciplines that have been central to the study of rhythm in music, which means that we will be able to draw upon a very large knowledge base. The work packages are organized in clusters in accordance with the angles above. The timeline of the project is illustrated in figure 2 below. The timeline illustrates the importance of the various perspectives for different phases of the project. In addition to ensuring an interdisciplinary approach to our research questions, these perspectives are important steps in an overall process whereby one phase of research produces some important premises for the next. More specifically, qualitative interviews with practitioners (A) will be important to identifying the foci of the

music analyses in B, and A and B will be absolutely crucial to identifying the hypotheses of the experimental work that will be undertaken in C. A, B, and C will provide the material for the analyses at the level of genre in D. Ultimately, the entire sequence of A, B, C, and D will feed into the cultural comparison in E (see figure 3). In the following, we describe the work packages and process in more detail.

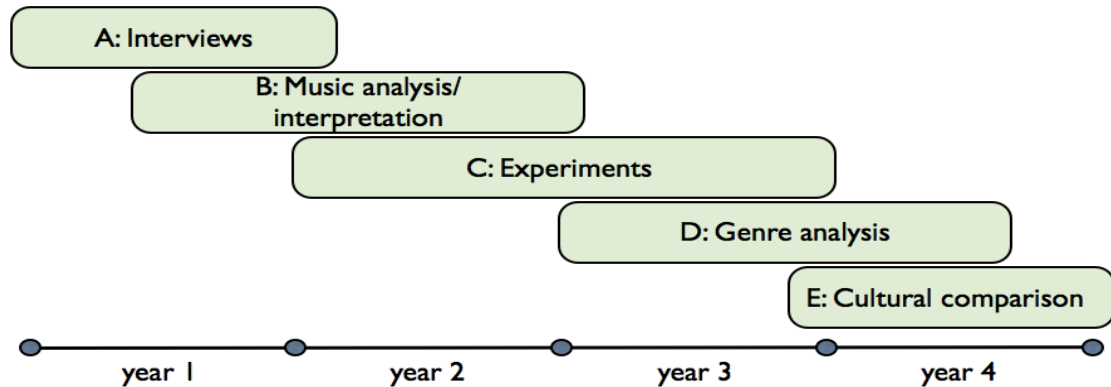


Figure 2. Main timeline of the four-year core period of the project. Prior to the core period, there will be a start-up and recruitment phase lasting six months, and following year 4 there will be a six-month termination period.

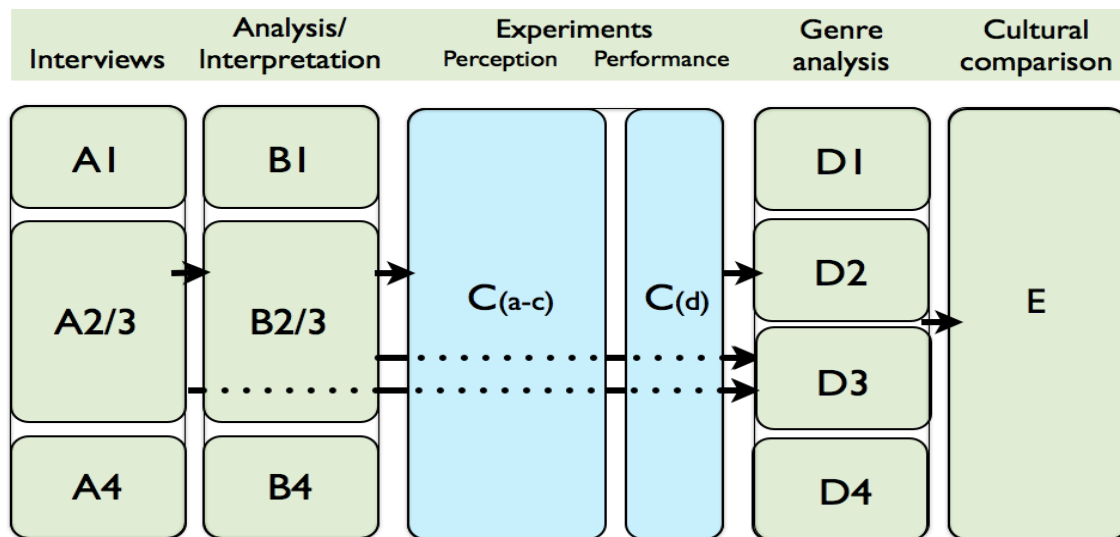


Figure 3. Overview and succession of work packages. Arrows indicate flow between the different parts of the project.

A1–4. *Qualitative interviews*. These work packages investigate the ways in which temporal and sound-related features at the micro level of music (here referred to as micro-rhythmic features) are articulated and valorized in different music traditions.

B1–4. *Music analysis and aesthetic interpretation*. The work packages in B involve musicological investigations of micro-rhythmic features in actual music, using examples from jazz, EDM, R&B/hip-hop, and fiddle music. Methodologically, we will rely on interpretive music-analytical studies of selected grooves from these music genres, with a focus on how sound phenomenally relates to and experientially influences temporal relationships, and vice versa. The analytical foci will be based on the outcome of the qualitative interviews in A1–4, as well as relevant previous research into timing and sound by, among others, the PI and her collaborators (cf. Bjerke 2010; Carlsen and Witek 2010; Danielsen 2006, 2010a, 2010b, 2012, 2015; Johansson 2010a, 2010b; Kvifte 2007; Polak 2010; Polak and London 2014; and Zeiner-Henriksen 2010).

C(a–c). *Perception experiments*. This work package consists of three experiments (a–c) aimed at investigating the ways in which sound and timing interact in perception. We will conduct tests in which musicians/producers with backgrounds in the different genres synchronize auditory clicks (experiment a),

visual markers (b), and body motion (c) with series of sounds. The methodology for experiment (c) was developed as part of a study conducted in collaboration with Assoc. Prof. Alexander Refsum Jensenius (Danielsen et al. 2015), using Qualisys motion-capture equipment in the FourMs motion-capture lab at the host institution's Dept. of Musicology (University of Oslo). The results demonstrate the significant impact that any change in the sound characteristics of beats has on motion patterns ($p < 0.05$), which supports the hypothesized connection between sound characteristics and perceived temporal position.

C(d): *Performance experiment*. This work package involves experimental research into the relationships between timing, sound, and sound-producing movements and seeks systematic knowledge about possible connections between aspects of motion, such as shape and velocity, and various properties of sound and timing in the *production* of rhythmic events. In the experiment, we will reverse the relationship between sound and timing, asking *to what extent and in what ways the timing of a rhythmic event also influences the production and/or perception of its sound*. The methodology in this work package derives from a study conducted in collaboration with Prof. Waadeland (Danielsen et al. 2015). Here, we instructed drummers to play early, late, and on-the-beat and found that the strokes that were instructed to be played late were consistently louder than strokes played on the beat ($p < 0.05$). We will test the findings of this pathbreaking study further in the present project, using a larger number of participants. We will also integrate movement into the investigations, based on our previous findings, by using motion-capture systems to study how drummers control their timing through different movements, and how this strategy influences the performed sounds (see also Dahl and Altenmüller 2008; Waadeland 2003, 2006).

D1–4. *Genre analysis*. In work package D1–4, findings from A, B, and C above will be analyzed and discussed in light of each other and existing literature in order to illuminate the genre-typical sound-timing relationships in each of the four musical genres: jazz, EDM, R&B/hip-hop, and fiddle music. We will zoom in on issues of “affiliation and continuity” as well as “dispute and displacement” (Toynbee 2000: 104), and also pay attention to gendered assumptions and valorizations. We will focus on both temporal and sound-related features, separately and in tandem, in order to identify the patterns and values that are typical of each genre, assessing to what extent a pattern or value is systematic enough to be considered typical for the actual genre. In particular, we will aim to relate the findings of C to values and aesthetic principles identified during the interviews, analysis, and interpretations of A and B.

E. *Cultural comparison*. In work package E, all results will be evaluated with regard to differences and similarities between genres and combined with existing knowledge about rhythm in musicology, ethnomusicology, and music psychology, all approached from a culturally comparative perspective. First, we will address the extent to which such features and combinations of features are culturally and aesthetically valid across genres. Second, we will reflect on the impact of musical-cultural background and training on auditory perception within the field of music, assessing the extent to which we find common patterns of perception across cultures, and the extent to which features and combinations of features are perceived *differently* across genres. Ultimately, we will discuss the extent to which our findings can be said to be valid for auditory perception in general.

THE RESEARCH GROUP

Principal Investigator (PI): Prof. Anne Danielsen (Dept. of Musicology, UiO) has extensive experience with the analysis of rhythm in played (Danielsen 2006) and computer-based music (Danielsen 2010a, 2012, 2014, 2015), as well as with interpreting and theorizing cultural and aesthetic aspects of rhythm in music (Danielsen 2006, 2012, 2016 forthcoming). She also has high competence in analyzing various aspects of sound using state-of-the-art music software, and in interpreting waveform graphs, sonograms, and other visual representations of sound (cf. Danielsen 2010a, 2012, 2014, 2015; Brøvig-Hanssen and Danielsen 2016). The PI has solid experience in conducting qualitative interviews (see, for example, Kjus and Danielsen 2015) and in recent years has been involved in empirical experimental research (Danielsen et al. 2014, Danielsen et al. 2015, and Danielsen et al. forthcoming). The success of the present project's multidisciplinary approach depends upon the PI's combination of a very specialized research focus (micro-rhythm in groove-based musics), developed during her PhD research into funk grooves and furthered in the project *Rhythm in the Age of Digital Reproduction*, and an unusually broad orientation with regard to research traditions and methodologies. The PI has extensive experience in research management through the projects *Rhythm in the Age of Digital Reproduction* (2004–2009, €750000, PI) and *Clouds and Concerts* (2011–2015, €1375000, PI); see also her CV. The project as presented demands the PI's multifaceted scholarly competence and leadership experience.

Prof. Georgina Born (Oxford, UK), adjunct professor at the host institution and an ERC advanced grant holder, is a world leader in research into music cultures from a comparative perspective (see, for example, Born and Hesmondhalgh 2000, and enclosed CV). Prof. Born will be part of the research group for four years of the project and serve as a mentor for its cross-cultural dimensions. Her expertise will be seminal to work package E (cultural comparison). In addition, she will assist with preparing the interviews of work package A and provide critical feedback on the entire project.

Assoc. Prof. Ragnhild Brøvig-Hanssen (Dept. of Musicology, UiO) has a very strong track record for a researcher at her career stage (Brøvig-Hanssen completed her PhD in musicology in 2013, supervised by the PI.) Her published works cover aesthetic, cultural, musical, and technological aspects of the impact of digital technology on rhythm and sound in contemporary technology-driven popular music genres (see, for example, Brøvig-Hanssen 2010; Brøvig-Hanssen and Danielsen 2016). She has served on the editorial board of Music Theory Online, as a reviewer for several publications, and as project coordinator and track chair for the 9th Art of Record Production Conference (see also enclosed CV). Brøvig-Hanssen will be involved in interviews, analysis, and interpretation relating to the computer-based music genres.

Assoc. Prof. Sophia Dahl (Aalborg University) is an adjunct professor in music cognition at the host institution. Dahl is highly experienced in experimental research and has published widely on drumming, rhythm, and motion, some of which is directly relevant to the present project (Dahl 2000, 2004; Dahl and Altenmüller 2008). Prof. Dahl will assist with experiment C(d).

Assoc. Prof. Alexander Refsum Jensenius (Dept. of Musicology, UiO) specializes in research into music and motion in general, and motion-capture methodology in particular. He has published extensively on these topics and has an impressive track record for a researcher at his career stage (see enclosed CV). Prof. Jensenius played a founding role in building up the fourMs motion capture lab at the host institution. He will take part in experiments c and d of work package C.

Assoc. Prof. Mats Johansson (Telemark University College, Norway) has published widely on the organization of time and playing style in Scandinavian traditional music, as well as on current questions of ownership and reproduction of this tradition in a transcultural context. His PhD thesis is an outstanding and highly innovative research-based contribution to the theory of musical rhythm, with its starting point as the typically non-isochronous (uneven) beat structure of Scandinavian folk music (see also enclosed CV). Johansson is trained as an ethnomusicologist and will be involved in the interviews, analysis, and interpretation of Scandinavian traditional fiddle music (work packages A4 and B4).

Prof. Justin London (Carleton College, USA) is a leading international scholar within music theory and music perception and cognition, and a specialist in research into meter and rhythm in music. He is past president of the Society for Music Theory and received international acclaim for his important book *Hearing in Time* (Oxford 2004, 2nd ed. 2012). He has extensive experience with experimental research into rhythm and meter, as well as sensorimotor synchronization to music (see also enclosed CV). Prof. London will serve as a mentor for all of the experimental work and will visit for two three-month periods to take part in C(a–c).

Dr. Rainer Polak (HfMT Köln, Germany) will be invited to the host institution for two periods of two to four weeks to be involved in workshops and give feedback on the experimental work in C(a–c). Dr. Polak is an ethnomusicologist who specializes in micro-rhythm and performance traditions in West African drumming, and he has published important and well-received articles on West African rhythm and non-isochronous meter (see Polak 2010; Polak and London 2014).

Prof. Carl Haakon Waadeland (Norwegian University of Science and Technology–NTNU, Norway) is experienced in performance research and has done extensive experimental research into rhythm in jazz and related genres (see Waadeland 2001, 2003, 2006). He is also a renowned jazz drummer and teacher at the highly successful jazz conservatory at NTNU in Trondheim, Norway, and he has cultivated a large network of jazz musicians (and particularly drummers). Prof. Waadeland will be involved in the motion capture experiments in C(d) in Oslo and Trondheim.

In addition two PhD students and two postdocs will be recruited.

Infrastructure and equipment (available):

- FourMs MoCap lab, Dept. of Musicology, University of Oslo (motion-capture equipment)
- Motion capture lab, Dept. of Music, NTNU, Trondheim (motion-capture equipment)
- Recording studios, Dept. of Musicology, University of Oslo

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