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"Hard" or "Soft": Shaping Microtiming through Sonic Features in Jazz-Related Groove Performance

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Timing, articulation, and phrasing are crucial to shaping rhythmic feel in jazz. It is through these elements that musicians fine-tune the style of performance. Most research into such performative qualities at the *micro* level of jazz rhythm is concerned with these rhythmic events' exact temporal positioning—that is, whether they are *early*, *late*, or *on time* in relation to some sort of reference point. In this article, we focus instead on the extent to which jazz musicians also use microrhythmic aspects *other* than temporal positioning to shape the micro level of rhythm in their performance. While microtiming focuses on the sound's "when," *microrhythm* takes into consideration a variety of additional features related to the sound's "what": attack (sharp or gradual?), duration (short or long?), decay (rapid or gradual?), pitch (high or low?), timbre (bright or dark?), and relative intensity.[1] Considering previous research into documented effects of acoustic factors on perceived microtiming we became interested in a) asking musicians to what extent they take such effects into account when shaping the rhythmic feel of their music, and b) to what extent such effects manifest in the music they make. We paid particular attention to whether they were aware of differences in perceived microtiming due to short and steep versus long and gradual attack phases (whether the attack is hard or soft) as well as the ways in which relative intensity (how loud a sound is in relation to its neighboring sounds), timbre (the overall color of a sound), and frequency content affect how we hear beat asynchronies and compound sounds.[2]

The study is situated within contemporary Norwegian jazz. As such, it is a case study of a particular jazz scene and its practices. However, it has implications for the broader fields of jazz studies and performance practice for two reasons. First and foremost, our focus on how musicians shape grooves at the microlevel has always been, and continues to be, a core aspect of the jazz tradition writ large.

[1] Anne Danielsen et al., "There's more to timing than time: Investigating musical microrhythm across disciplines and cultures," *Music Perception* (forthcoming).

[2] Today, research on timbre also considers envelope (ADSR) as a parameter of timbre. See Kai Siedenburg and Stephen McAdams, "Four Distinctions for the Auditory 'Wastebasket' of Timbre," *Frontiers in Psychology* 8 (2017). https://doi.org/10.3389/fpsyg.2017.01747

Furthermore, Scandinavian jazz, since at least the 1950s, has been internationally oriented and therefore representative of broader pedagogical and performance practices. This orientation can be traced back to Swedish saxophone player Lars Gulling's collaborations with, among others, James Moody, Clifford Brown, Lee Konitz and Chet Baker. In the 1960s a new generation of Scandinavian musicians, among them Jan Garbarek, Palle Danielsson, and Terje Rypdal, collaborated with Keith Jarrett, Pat Metheny, Chick Corea, Charlie Haden and others, on several albums released on the German-based label ECM, many of which were recorded in the Oslo-based studio Rainbow under the supervision of sound engineer Jan Erik Kongshaug. Some examples from recent decades include guitarist Knut Værnes' (one of the informants in this study) collaboration with drummer Omar Hakim, and Norwegian bassist Ingebrikt Haaker Flaten and drummer Paal Nilsen Love's collaboration with multi-instrumentalist John McPhee.

Methodologically, this study is situated within a qualitative, humanistic tradition and relies on the authors' analyses and interpretations of the discourse and aesthetic practices of selected expert jazz musicians that are currently active on the Norwegian jazz scene. We begin with an overview of existing research into groove and microrhythm in jazz studies and auditory perception studies. We then present results from our interviews with expert musicians, as well as two analyses of selected performances in which we focus on how these musicians use some of the techniques they describe in the interviews. Lastly, we discuss these results in light of findings from research into perceived timing and auditory stream segregation, draw certain conclusions, and point out some implications for further research.

GROOVE, FEEL AND MICRORHYTHMIC INTERACTION IN JAZZ

The importance of microlevel interactions among musicians to the experience of jazz grooves first came into focus when Charles Keil introduced his "PD theory" (1987), which suggests that it is the "participatory discrepancies" generated among performers' rhythms at the microrhythmic level that create various "process"-related feels of "'beat,' 'drive,' 'groove,' 'swing,' 'push,' etc."[3] Many ethnographic studies of performance in jazz ensembles have documented the importance of such microlevel interaction to the feel and aesthetic quality of jazz performance. Based on interviews as well as analyses of musical examples, Monson (1996) pointed to "interactiveness" as a core value shared by the comp musicians in a jazz combo. Similarly, Doffman (2009) combined in-depth microtiming analysis of musical interaction with reports from musicians participating in a live trio jazz performance to uncover a dialogical approach to groove that results in minute, but very specific, microtiming interactions.[4] Berliner's informants (2009) also stressed the importance of a shared sense of

[3] Charles Keil, "Participatory Discrepancies and the Power of Music," *Cultural Anthropology* 2, no. 3 (1987): 275–283. Defining groove can be challenging and its meaning may vary with the context. Barry Kernfeld describes its meaning in jazz as "a persistently repeated pattern," see Kernfeld, "Groove (i)," *New Grove Dictionary of Jazz*, 2nd ed., Grove Music Online, Oxford Music Online (2017), available at: http://www.oxfordmusiconline.com/subscriber/article/grove/music/J582400 (accessed July 3, 2023). Broadly speaking, three main understandings of groove have arisen across the different disciplines engaged in groove studies: (1) groove as patterns and performance, (2) groove as pleasure and appeal to movement, and (3) groove as a state of being, see Guilherme Schmidt Câmara and Anne Danielsen, "Groove," in *The Oxford Handbook of Critical Concepts in Music Theory*, ed. Alexander Rehding and Steven Rings, 271–294. (Oxford: Oxford University Press, 2018). The first approach is prevalent in musicology, ethnomusicology, and music theory, whereas the second tends to dominate in the field of music psychology, where groove has largely come to mean a "pleasurable urge to move," see Petr Janata, Stefan T. Tomic, and Jason M. Haberman, "Sensorimotor Coupling in Music and the Psychology of the Groove," *Journal of Experimental Psychology: General* 141, no. 1 (2012): 54–75; Guy Madison, "Experiencing Groove Induced by Music: Consistency and Phenomenology," *Music Perception* 24, no. 2 (2006): 201–208. The third approach associates groove with engendering an almost euphoric experience of "being in the groove," see Anne Danielsen, *Presence and Pleasure: The Funk Grooves of James Brown and Parliament* (Middletown, Conn.: Wesleyan University Press, 2006); Tiger C. Roholt, *Groove: A Phenomenology of Rhythmic Nuance* (New York: Bloomsbury Academic, 2014). These various yet related approaches highlight the intricate, complex relationship between the groove's specific rhythmic qualities and the experience of the groove overall.

[4] Ingrid Monson, *Saying Something: Jazz Improvisation and Interaction* (Chicago: University of Chicago Press, 1996); Doffman, "'Making It Groove!' Entrainment, Participation and Discrepancy in the 'Conversation' of a Jazz Trio," *Language and History* 52, no. 1 (2009): 130–147.

beat and "getting into the groove"; in the words of drummer Charli Persip, "You ride right down that groove with no strain and no pain—you can't lay back or go forward. That's why they call it a groove. It's where the beat is, and we're always trying to find that."[5] Critical to the quest for the groove is the optimal combination of the timing and articulation of different instruments through listening for "a certain sound," adds bassist Chuck Israels.[6] Likewise, in an interview study focused on the improvisational thinking of jazz musicians wherein the informants were also asked to improvise a solo, Norgaard (2011) found that rhythmic feel affects note placement, duration, melodic shape, and inflection in this decision-making process.[7]

Keil's insight brought much attention to microtiming in music theory and music cognition/psychology in the decades that followed his early work. Most research into microtiming and feel, however, has concerned itself with the significance of a sound's exact temporal positioning in relation to a virtual reference structure that has often been conceptualized as a series of isochronous points in time. Moreover, swing is often approached and defined in purely temporal terms as a ratio between the two eighth notes of a given beat (also called the beat–upbeat ratio or BUR).[8]

Following Keil, then, many theoretical, musicological, and ethnographic inquiries have pointed to microtiming nuances as crucial to achieving the desired groove or rhythmic feel of jazz and related forms of groove-based music.[9] Some

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[5] Paul F. Berliner, *Thinking in Jazz: The Infinite Art of Improvisation* (Chicago: University of Chicago Press, 2009), 349.

[6] Israels quoted in Berliner, *Thinking in Jazz*, 351.

[7] Martin Norgaard, "Descriptions of Improvisational Thinking by Artist-Level Jazz Musicians," *Journal of Research in Music Education* 59, no. 2 (2011): 110.

[8] Fernando Benadon, "Slicing the Beat: Jazz Eighth Notes as Expressive Microrhythm," *Ethnomusicology* 50, no. 1 (2006): 73–98. See also Geoffrey L. Collier and James L. Collier, "An Exploration of the Use of Tempo in Jazz," *Music Perception* 11, no. 3 (1994): 219–242; Anders Friberg and Andreas Sundström, "Swing Ratios and Ensemble Timing in Jazz Performance: Evidence for a Common Rhythmic Pattern," *Music Perception* 19, no. 3 (2002): 333–349; J. A. Prögler, "Searching for Swing: Participatory Discrepancies in the Jazz Rhythm Section," *Ethnomusicology* 39, no.1 (1995): 21–54; Mathew Butterfield, "The Power of Anacrusis: Engendered Feeling in Groove-Based Musics," *Music Theory Online* 12, no. 4 (2006), http://www.mtosmt.org/issues/mto.06.12.4/mto.06.12.4.butterfield.html (accessed May 14, 2021).

[9] See, for example, David Ake, *Jazz Cultures* (Berkeley: University of California Press, 2002); Benadon, "Slicing the Beat"; Ingmar Bengtsson and Alf Gabrielsson, "Analysis and Synthesis of Musical Rhythm," in *Studies in Music Performance*, ed. J. Sundberg (Stockholm: Royal Swedish Academy of Music, 1983), 27–60; Butterfield, "The Power of Anacrusis"; Matthew Butterfield, "Why Do Jazz Musicians Swing Their Eighth Notes?," *Music Theory Spectrum* 33, no. 1 (2011): 3–26; Câmara and Danielsen, "Groove"; Danielsen, *Presence and Pleasure*; Anne Danielsen,

of this work indirectly touches upon the interaction between the domains of pitch and time in jazz performance. Monson, for example, quotes bassist Cecil McBee's observation that the rhythmic flow is what frames and integrates the "remaining musical elements"—that is, harmony, melody, and timbre.[10] Ake and Iyer have also stressed the critical role of various sonic features in swing and performed microrhythm.[11] Indeed, Keil himself touched upon the question of the extent to which the choice of sounds and instruments, as well as the sonic treatment of those sounds, contributes to groove in his early writings on participatory discrepancies. He discusses, for example, how the vital drive of a groove can be generated through the rhythm section's attack—that is, "the type of contact the player makes with his instrument in the initial production of a note."[12] Similarly, Bengtsson and colleagues theorized that the range of systematic microvariations (SYVAR) could encompass frequency, amplitude, envelope, and spectrum.[13] Their main theoretical and empirical focus, however, was on duration (SYVAR-D), and specifically the systematic variations in the chronometric temporal relations of sonic events. Pressing conducted a study in music psychology by recording himself performing two jazz improvisations and then extracting details related to his timing, dynamics, and "legato-ness" with a computer.[14] Two decades later, however, Fernando Benadon, in an article locating jazz swing in the interplay among rhythm, melody, and harmony, pointed to the still widespread tendency to neglect "the interaction between the pitch and time domains" in research into microrhythm.[15]

Somewhat surprisingly, sound features such as envelope shape, intensity, and timbre were until then also largely neglected in research into timing within the more general field of auditory perception.[16] In recent years, however, research

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"Pulse as Dynamic Attending: Analysing Beat Bin Metre in Neo Soul Grooves," in *The Routledge Companion to Popular Music Analysis: Expanding Approaches*, ed. Ciro Scotto, Kenneth M. Smith, and John Brackett (New York: Routledge, 2018), 179–189; Vijay Iyer, "Embodied Mind, Situated Cognition, and Expressive Microtiming in African-American Music," *Music Perception: An Interdisciplinary Journal* 19, no. 3 (2002); Monson, *Saying Something*.

[10] Monson, *Saying Something*, 28.

[11] Ake, *Jazz Cultures*; Iyer, "Embodied Mind."

[12] Charles Keil, *Urban Blues* (Chicago: University of Chicago Press, 1966), 341.

[13] Ingmar Bengtsson, Alf Gabrielsson, and Stig-Magnus Thorsén, "Empirisk rytmforskning," *Svensk tidsskrift för musikforskning* (1969): 95–96.

[14] Jeffrey Lynn Pressing, "Improvisation: Methods and Models," in *Generative Processes in Music: The Psychology of Performance, Improvisation, and Composition*, ed. John Sloboda (New York: Oxford University Press, 1987), 129–178.

[15] Benadon, "Slicing the Beat," 73.

[16] Michael Schütz and Jessica Gillard, "On the Generalization of Tones: A Detailed Exploration of Non-Speech Auditory Perception Stimuli," *Scientific Reports* 10 (2020): 1–14.

into effects of various acoustic factors on perceived timing in music and speech, has highlighted the ways in which timing interacts with a variety of acoustic factors.[17] Accordingly, performance experiments have found that instructed timing also tend to systematically influence acoustic factors such as attack, intensity, and overall duration, although in different ways for different instruments.[18] In the next section, we will give an overview of the most important findings from existing research into microlevel auditory perception and music performance.

MICROLEVEL INTERACTION BETWEEN SONIC FEATURES AND PERCEIVED TIMING

It is well known that sounds produced by different musical instruments have different onset and attack-phase characteristics related to the manner of their manipulation: one blows a reed instrument, bows or plucks a string, strikes a membrane, and so on.[19] Musicians take these differences into account while striving to achieve ensemble synchrony.[20] Previous research into timing perception has also shown that some sounds are more *elastic* than others in terms of achieving this synchrony (compare, for example, the task of aligning two bowed string instruments versus two drum hits). As Johansson has argued, the tolerance window for the temporal precision with which such a synchronization task must be achieved varies with not only the features of the sound but also the

[17] Anne Danielsen et al., "Where Is the Beat in That Note? Effects of Attack, Duration and Frequency on the Perceived Timing of Musical and Quasi-Musical Sounds," *Journal of Experimental Psychology: Human Perception and Performance* 45, no. 3 (2019): 402–418; Justin London et al., "A Comparison of Methods for Investigating the Perceptual Center of Musical Sounds," *Attention, Perception, and Psychophysics* 81, no. 6 (2019): 2088–2101; for a review regarding speech, see Rudi Villing, "Hearing the Moment: Measures and Models of the Perceptual Centre" (Ph.D. diss., National University of Ireland, 2010).

[18] Guilherme Schmidt Câmara et al., "Effects of Instructed Timing on Electric Guitar and Bass Sound in Groove Performance," *Journal of the Acoustical Society of America* 147 (2020): 1028–1041; Guilherme Schmidt Câmara et al., "Timing Is Everything . . . Or Is It? Effects of Instructed Timing Style, Reference, and Pattern on Drum Kit Sound in Groove-Based Performance," *Music Perception* 38, no. 1 (2020): 126; Anne Danielsen et al., "Effects of Instructed Timing and Tempo on Snare Drum Sound in Drum Kit Performance," *Journal of the Acoustical Society of America* 138, no. 4 (2015): 2301–2316.

[19] See Thomas Rossing, Richard Moore, and Paul Wheeler, *The Science of Sound*, 3rd ed. (Upper Saddle River, N.J.: Pearson Education, 2002), 190–334.

[20] Rudolf Rasch, "Synchronization in Performed Ensemble Music," *Acoustica* 43, no. 2 (1979): 121–131.

stylistic expectations of the genre in question.[21] In some Scandinavian fiddle-music styles, for example, the temporal window for simultaneous sound events is huge—over one hundred milliseconds. In some funk and funk-derived musical genres, we also find considerable and varying onset discrepancies between rhythmic events otherwise meant to be articulating the same beat.[22] The perceived temporal position of a sound—that is, its *perceptual center* (P-center)[23]—is therefore much more than a particular instant within the microstructure of a musical or spoken sound. In fact, the P-center has a temporal duration and shape; in a repetitive musical context, it functions less as a point in time than as an extended "beat bin," a term introduced by Danielsen to account for the perceptual counterpart to extended musical beats.[24]

As to how specific sonic factors influence the P-centers of musical sounds, research has found that a fast attack—that is, a shorter rise time from onset to energy peak—leads to an earlier P-center, and, conversely, a longer rise time leads to a later P-center.[25] A short rise time typically produces a sharp or hard, percussive attack, whereas a longer rise time results in a softer, more gradual

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[21] Mats Johansson, "The Concept of Rhythmic Tolerance: Examining Flexible Grooves in Scandinavian Folk-Fiddling," in *Musical Rhythm in the Age of Digital Reproduction*, ed. Anne Danielsen (Farnham, Surrey: Ashgate/Routledge, 2010).

[22] Danielsen, *Presence and Pleasure*; Kristoffer Bjerke, "Timbral Relationships and Microrhythmic Tension: Shaping the Groove Experience through Sound," in *Musical Rhythm in the Age of Digital Reproduction*, ed. Anne Danielsen (Farnham, Surrey: Ashgate/Routledge, 2010), 85–101; Kristoffer Carlsen and Maria Witek, "Simultaneous Rhythmic Events with Different Schematic Affiliations: Microtiming and Dynamic Attending in Two Contemporary R&B Grooves," in *Musical Rhythm in the Age of Digital Reproduction*, ed. Anne Danielsen (Farnham, Surrey: Ashgate/Routledge, 2010), 51–68; Anne Danielsen, "Here, There and Everywhere: Three Accounts of Pulse in D'Angelo's 'Left and Right,'" in *Musical Rhythm in the Age of Digital Reproduction*, ed. Anne Danielsen (Farnham, Surrey: Ashgate/Routledge, 2010), 19–36; Ragnhild Brøvig-Hanssen and Anne Danielsen, *Digital Signatures: The Impact of Digitization on Popular Music* (Cambridge, Mass.: MIT Press, 2016); Danielsen, "Pulse as Dynamic Attending.

[23] John Morton, Steve Marcus, and Clive Frankish, "Perceptual Centers (P-Centers)," *Psychological Review* 83, no. 5 (1976): 405–408.

[24] Danielsen, "Here, There and Everywhere"; Danielsen et al., "Effects of Instructed Timing and Tempo on Snare Drum Sound in Drum Kit Performance"; Danielsen, "Pulse as Dynamic Attending; Danielsen et al., "Where Is the Beat in That Note?"

[25] Joos Vos and Rudolf Rasch, "The Perceptual Onset of Musical Tones," *Perception and Psychophysics* 29 (1981): 323–335; John W. Gordon, "The Perceptual Attack Time of Musical Tones," *Journal of the Acoustical Society of America* 82, no. 1 (1987): 88–105; Piet G. Vos, Jiří Mates, and Noud W. van Kruysbergen, "The Perceptual Centre of a Stimulus as the Cue for Synchronization to a Metronome: Evidence from Asynchronies," *Quarterly Journal of Experimental Psychology* 48, no. 4 (1995): 1024–1040; Danielsen et al., "Where Is the Beat in That Note?"; London et al., "A Comparison of Methods for Investigating the Perceptual Center of Musical Sounds."

attack phase. In his seminal study, Gordon also found that, for sounds with shorter rise times, the P-center (or "perceptual attack time" [PAT] in his terminology) is primarily determined by amplitude cues; when a sound's rise time is longer, its PAT is also influenced by spectral features.[26] Previous research also points to the effect of total *duration* on P-center, in that longer durations tend to produce later P-centers.[27]

As to the influence of various sonic factors on the temporal extent of beats, the findings regarding the effect of rise time are particularly clear: sounds with slow rise times (soft attack) have both later P-centers and wider beat bins.[28] Ultimately, several ethnographic, ethnomusicological, and musicological studies have shed further light on the ways in which acoustic factors interact with stylistic expectations. What is heard to be on the beat (or within the beat bin) may, however, vary across musical genres.[29]

The relationships among the various rhythmic layers in a groove also play a role in the perception of timing and microrhythmic feels, since sounds, in a

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[26] Gordon, "The Perceptual Attack Time of Musical Tones," 88–105.

[27] J. C. Seton, "A Psychophysical Investigation of Auditory Rhythmic Beat Perception" (Ph.D. diss., University of York, 1989); S. K. Scott, "The Point of P-Centres," *Psychological Research* 61, no. 1 (1998): 4–11; Vos, Mates, and Kruysbergen, "The Perceptual Centre of a Stimulus as the Cue for Synchronization to a Metronome"; Danielsen et al., "Where Is the Beat in That Note?"; London et al., "A Comparison of Methods for Investigating the Perceptual Center of Musical Sounds." Regarding other acoustical factors, the picture is less clear. A few studies indirectly investigate the effect of *frequency content* on P-center location, but the results are not consistent, see, for example, Seton, "A Psychophysical Investigation of Auditory Rhythmic Beat Perception"; Michael J. Hove, Peter E. Keller, and Carol L. Krumhansl, "Sensorimotor Synchronization with Chords Containing Tone-Onset Asynchronies," *Perception and Psychophysics* 69, no. 5 (2007): 699–708. One study that directly investigates the effect of frequency content on P-center location is Danielsen et al., "Where Is the Beat in That Note?". Here the results show that lower frequency led to later P-center for musical sounds.

[28] Matthew J. Wright, "The Shape of an Instant: Measuring and Modeling Perceptual Attack Time with Probability Density Functions" (Ph.D. diss., Stanford University, 2008); Danielsen et al., "Where Is the Beat in That Note?"; London et al., "A Comparison of Methods for Investigating the Perceptual Center of Musical Sounds."

[29] For Scandinavian fiddle music, see Mats Johansson, "Rhythm into Style: Studying Asymmetrical Grooves in Norwegian Folk Music" (Ph.D. diss., University of Oslo, 2010) and Haugen, "Music-Dance"; for hip-hop and neosoul, see Bjerke, "Timbral Relationships and Microrhythmic Tension"; Carlsen and Witek, "Simultaneous Rhythmic Events with Different Schematic Affiliations"; Danielsen, "Here, There and Everywhere"; Brøvig-Hanssen and Danielsen, *Digital Signatures*; Danielsen, "Pulse as Dynamic Attending"; and Anne Danielsen, "Glitched and Warped: Transformations of Rhythm in the Age of the Digital Audio Workstation," in *The Oxford Handbook of Sound and Imagination*, vol. 2, ed. Mark Grimshaw-Aagaard, Mads Walther-Hansen, and Martin Knakkergaard (New York: Oxford University Press, 2019), 595–610.; for jazz, see Iyer, "Embodied Mind," and Monson, *Saying Something*.

musical context, are not experienced in isolation but as part of a multifaceted texture of auditory streams that occasionally present sounds simultaneously to the listener. Fascinatingly, humans are able to organize such a complex musical texture into meaningful elements and, along the way, distinguish one sound stream from another. The stream-segregating processes of human auditory perception have been thoroughly studied and theorized by Albert Bregman.[30] According to Bregman, we do this by way of primitive grouping processes, on the one hand, and cognitive schemas derived from our previous experiences with sounds, on the other. These processes give rise to *stream segregation*, which Bregman defines as "a sequence of auditory events whose elements are related perceptually to one another, the stream being segregated perceptually from other co-occurring auditory events."[31] A set of sounds with higher frequencies that occurs simultaneously with a set of sounds with lower frequencies will, for example, be organized into two streams if the gap in frequency is large enough and/or the intervals between the respective sounds in the sets are short enough. Sound sets with not enough discrepancy in frequency and time in their intervals with their surrounding sounds will more likely be grouped together as a single stream of compound sounds instead. Factors such as intensity and timbre also affect grouping: sudden increases in intensity create unit boundaries, and we tend to group bright sounds, for example, with other bright sounds.[32] Relatedly, location in space makes a difference. Primitive scene analysis tends to group sounds that come from the same spatial location and segregate sounds that come from different places.[33] These grouping processes are all relevant to perceived timing since whether we hear sounds as belonging to the same or different streams, will affect how we perceive the temporal relationship between them.

The results of this research into microlevel auditory perception have been obtained through both controlled and more interpretive empirical studies. It remains an open question, however, whether musicians adjust sonic features to influence perceived timing by intuition only or whether they are already aware

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[30] Albert Bregman, *Auditory Scene Analysis: The Perceptual Organization of Sound* (Cambridge, Mass.: MIT Press, 1990), 644.

[31] Albert Bregman and Jeffrey Campbell, "Primary Auditory Stream Segregation and Perception of Order in Rapid Sequences of Tones," *Journal of Experimental Psychology* 89, no. 2 (1971): 244–249.

[32] Bregman, *Auditory Scene Analysis*, 644.

[33] For example, if speech is rapidly switched back and forth between the ears, it produces a sudden rise of intensity in one ear and a sudden drop in the other. We treat these changes in our two ears as distinct events, even though there would be no net change in the signal if we combined the two inputs. This effect occurs when we listen to a click as well, in that the click rate will appear to slow when the sounds are alternated between the two ears in relation to when the sounds all come to the same ear (ibid., 645).

of these effects and take them into consideration in their practice. In what follows, we will present results from our interviews with expert jazz musicians concerning this question. Our focus was on the ways in which they viewed the relationship between the acoustic properties of a single rhythmic event and its timing, as well as the extent to which they use such insights in their respective performance or production practices. Our expectation was that controlling microrhythmic aspects such as temporal onset, attack shape, relative intensity, and timbre would be a concern among the interviewees, and that the interaction with other musicians would be a focal point in this regard. We were not sure about the extent to which the musicians were aware of and actively use sonic features to shape timing.

INTERVIEWS WITH EXPERT MUSICIANS

Methods

We conducted in-depth semi-structured interviews with five expert, jazz-trained performers whose main instruments were, respectively, vocals, saxophone, guitar, bass, and drums. All saw music as their primary area of work and were presently active in the Norwegian jazz scene. (A complete list of interviewed artists and their websites appears in Table 1.) One interview typically lasted between sixty and ninety minutes.

Table 1. Musicians Interviewed

Name	**Instrument**	**Website**
Sofie Tollefsbøl	Vocals	https://www.fiehmusic.com/
Ola Øverby	Drums	https://www.facebook.com/Damatatrio https://www.fiehmusic.com/
Knut Værnes	Guitar	http://www.knutvarnes.no/
Morten Halle	Saxophone	https://mortenhalle.no/
Ellen Andrea Wang	Bass & Vocals	https://ellenandreawang.com/

When recruiting informants, we ensured that they covered the main instruments of a typical jazz ensemble, drawing from both rhythmic and melodic sections. The informants also cover several generations of musicians: Morten Halle (saxophone) and Knut Værnes (guitar) have long-term experience as jazz

performers since the late 1970s, as well as experience as session musicians in funk, soul, pop, and rock-related contexts. Ellen Andrea Wang (double bass and vocals) has been active both as a solo artist and with various other jazz groups such as Pixel and GURLS since the early 2000s. The youngest informants, Sofie Tollefsbøl (vocals) and Ola Øverby (drums) are key members of the soul/funk band Fieh (formed in 2014). Øverby also contributes regularly to various other jazz and rock projects. All our informants have received education from one of the major Norwegian jazz academies. Despite going in new directions in their subsequent careers, through their education they were trained to perform more traditional jazz styles, such as bebop, and aware of the tradition's history and its origins in African-American musicking.

The interviews were conducted in 2017 and 2018 and carried out by a team including one senior researcher and two research assistants, all of whom were very familiar with the genre as well. We followed a semi-structured interview guide that started with the informant's general view of what a good groove is, then moved on to more specific questions about the importance of timing, sonic features, and their interactions at the micro level of rhythm. In the last part of the interview, we asked questions about specific jazz topics and the similarities and differences between their main genre and other genres with which they had experience. We formulated our questions in an open manner—that is, how/what/why rather than yes/no—to encourage varied perspectives and avoid influencing the responses. We also tried to actively follow up on those responses in the interviews.

We conducted the interviews in Norwegian, and the two research assistants transcribed and coded them using the software f4transcript (https://www.audiotranskription.de/english/f4) and f4analysis (https://www.audiotranskription.de/english/f4-analyse). We used a custom-made code book developed by the research group, which was structured in a hierarchical manner derived from the sections and subsections. We then did systematic searches in the material both within and across topics and extracted all relevant statements pertaining to the topics of the article. Ultimately, we culled and translated into English exemplary and particularly illuminating statements for inclusion in this article. When citing these interviews, we include the source to allow the reader to associate the insight with the individual responsible for it. For some key terms we provide the original Norwegian word in squared brackets next to the English translation.

Effects of Attack Shape

The interview transcripts with the jazz-trained musicians reveal several factors that come into play in the relationship between the sonic characteristics and the perceived timing of rhythmic events in their performance. One factor in this relationship involves the playing technique required to produce different sounds, dynamics, and accents, as well as the general sound quality of specific instruments. Vocalist Sofie Tollefsbøl also reflects on the importance of the sound of different words in this context: "What I often think about is that [in] a lot of hip-hop and rap… the sound of the words really has everything to say. That the word has a sound or a consonant… creates a rhythmic effect in a way."

A first observation across our interviewees is that the terms soft [myk] and sharp [skarp] ("sharp" indicating the opposite of "soft," better semantically translated as "hard" for the purposes of this study) are used intuitively by the musicians to describe sound–timing relations. For example, Ellen Andrea Wang, a double bassist and vocalist, perceives hard and soft sounds as opposites and experiences them as pushed and pulled, respectively. In the context of her bass, when she wants to play pushed or "wants it to 'pop' a little more, the attack [on the string] is harder." According to Wang, such "popped" sounds always anticipate the beat. If she is playing behind, on the other hand, the sound is softer. Soft sounds are also more flexible: "If the groove is going, soft sounds may 'live' a little more timing-wise." Taken together, the hard and soft sounds create what she describes as "waves and movement" in the music: "Drums and bass are the timekeeper, groove machinery. We develop grooves, improvise around them, and then the pianist or keyboardist has a separate universe where it is allowed to float around and stick out a little." Guitarist Knut Værnes also points out that when he wants to play in a laid-back manner, he often switches from a pick to his fingers, both to change the playing technique and to produce a different sound: "You don't get that fast attack that you get with a pick. You get a much softer attack. A pick is a little pointy plastic thing, which says 'pluck,' while with your finger you can stroke the string a bit more."

Værnes elaborates by noting that fingerpicking engages a whole joint in each attack, and when the finger makes contact with the string, it slides a bit before letting it go, which is a more delayed process of sound production than that of a pick. Saxophone player Morten Halle comments: "If you think about sound in a room, bass comes later." According to Halle, bassists thus take pitch into consideration: "The deeper the note, the earlier you have to play for it to sound right." He also notes that context matters when he shapes sounds on the saxophone—there is a big difference between studio-produced jazz fusion recordings featuring complex patterns of what he refers to as "mathematically

correct" subdivisions and "looser" live jazz formats involving physical distance between the performers and the microphones. Jazz fusion, that is, demands a "sharper, tweaked sound" to articulate the complexity of its intricate rhythms, whereas "looser" jazz styles do not require the same sonic clarity. In turn, Halle emphasizes the specific impact of these percussive sounds: "The conscious use of a harder attack relative to the melodic and rhythmic function can give the instrument a double role. Besides carrying the melody and having a consistent flow, you also have accents that kick into the rhythm section." However, even when the groove is very tight and precise, he prefers a sound that is not *too* hard: "If one is to play a very precise onset, it is in fact not that accurate, since the sound actually starts and opens up. It's not just a point."

Effects of Frequency, Dynamics, and Timbre

For vocalist Sofie Tollefsbøl, *timbre* can in itself be the basis for the rhythmic flow. If, for example, the kick drum sounds, in her words, "fat," the rest of the band will play in a more laid-back fashion, even if the beat itself is not so: "Perhaps he [drummer Ola Øverby] does not really play behind, but . . . the band will start playing more laid-back when the bass drum gets heavier. Hmm. Or sounds 'fatter.'" When she is asked about what kinds of sounds one chooses for a snappier funk feel, for example, she explains: "Well, I just think brighter . . . Brighter sounds in a way, but I do not know why I do it [like that]." Bandmate Ola Øverby agrees:

> If I think about it, there is often a kind of tendency for dark things to come a little later… If it's a symphony orchestra arriving at some insane climax, then it is often as if the bass and timpani… sound a bit later, because they are such heavy instruments, sort of… There is probably science on that—I have no real proof. But there is something about the big dark instruments, you spend more time on the atta[ck]… [on] hearing the sound itself. So that, somehow, when the violin and the flutes just put it "there" [claps hands together], then you will in a way hear the bass a little after.

Øverby also stresses the importance of dynamics: "[Dynamics] have an insane amount to say, then. It is, in a way, the second most important [thing] . . . after the actual timing." He uses the snare drum as an example: "If [the snare drum] is louder dynamically, it has a completely different function in the groove than if played more quietly." Using playing technique to shape this function or feel is critical, he observes. During his interview Øverby demonstrates various strokes on a ride cymbal to illustrate the ways in which he produces different sounds that could be perceived as either more pushed or more laid back. Crucial aspects of this work include the grip, the actual impact of the stick, and the location of that

impact on the cymbal, and the results range between higher-frequency sounds with shorter rise times and lower-frequency sounds with longer rise times. Øverby perceives the former as more pushed, but at the same time problematizes the concept: "If you want the sound itself [in isolation] to be pushed, that is in a way impossible.… You have to be ahead of… that which you *think* you are playing in relation to… you have to create the illusion of the sound itself being pushed or laidback" [italics added]. In short, that is, a sound can only be perceived as pushed in relation to something else. He does acknowledge that softer and slower-rising sounds are more readily perceived as laid back in and of themselves, however: "[Without a pulse reference], one has to create the illusion, the feeling of the sound itself being on top or laying back . . . it's something about the soft and slow that is more behind in itself. Whereas the light, sharp, and fast is more on top, in a way."

Combining Sounds with Different Characteristics

As noted above, within an ongoing stream of sound, shifts in intensity can alter the perceived temporal relationships among the individual sounds themselves, especially in drumming. Øverby insists, "If there is a steady stream of eighth notes and the snare is played weaker on the fifth hit, then it doesn't really have an effect on the groove. But if that note is *louder*, it will affect the whole feel, and thus it affects the timing, in a way." Halle agrees: "A typical example [of the manipulation of timing feel] with a drummer is to adjust the balance timewise between the sounds you're playing, but also at the same time the volume and articulation of the sounds plays a big role." Since the shaping of the sounds itself has such a huge impact on timing feel—as mentioned above, a percussive sound *behaves* differently from a softer or more muffled sound—they may need to be placed differently as well, Halle continues. Also, if a hard and a soft sound occur at the same time, Halle would perceive the soft sound first, but, he says, "where the heavy, big, warm sounds are *not*—where there's some room—there is space for the smaller, sharper [skarpere] sounds that tell us something about what that first heavy, warm sound means. About where it was placed. That it is actually defined by the other sounds" [emphasis added].

Here, Halle elaborates upon Wang's observation that soft sounds are "harder to nail down" because they "float more freely" in a rhythmic sense; while this may be true, those soft sounds can be located more specifically by the "running commentary" on their perceived location supplied by the percussive sounds nearby. That is, in a horizontal stream, a succeeding fast-attack sound will influence the perceived timing of previous sounds. When asked about

simultaneous sounds—for example, a sharp sound stacked atop a rounded double bass sound—Halle says, "I would think that the round [soft] sound comes first."

Drummer Ola Øverby mentions that he senses friction between two sounds that coincide with only a small temporal delay at the micro level if they are similar in frequency and timbre. On the other hand, if they are further apart in their frequency, he tends to perceive them as "working together on the same hit." He also demonstrates this phenomenon by producing compound sounds on the drums to illustrate the greater tolerance for deviation in timing between sounds that are further apart in frequency.

Discussion

In sum, different instruments and different playing techniques produce different sonic features that enable these jazz musicians to suggest either pushed or laid-back timing at a micro level. In particular, the ability to articulate a note as hard (early) or soft (late) establishes not only a beat location but also a beat *shape*—and, in turn, a timing feel. This connection accords with empirical findings reported in behavioral research involving the perceptual center or "moment of occurrence" of musical sounds, as well as in controlled studies of the sound features used by professional instrumentalists to generate pushed, on-the beat, and laid-back timing feels.[34] Our interviewees also describe harder, percussive sounds as more precise in terms of timing than the softer and more laid-back sounds, which, again, are shaped so as to be flexible in this regard. This conclusion aligns with the results for variability of tests of the perceptual center of sounds with short and long rise times, respectively. Several studies report that the former sounds produce a narrower window of possible synchronization points, whereas the latter sounds demonstrate much wider "beat bins."[35] In that case, of course, a greater portion of the sound's duration can be used to align it with another sound under the guise of relative synchrony.

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[34] Danielsen et al., "Effects of Instructed Timing and Tempo on Snare Drum Sound in Drum Kit Performance"; Câmara et al., "Effects of Instructed Timing on Electric Guitar and Bass Sound in Groove Performance"; Câmara et al.,"Timing Is Everything." P-center was defined as "moment of occurrence" by Morton, Marcus, and Frankish in "Perceptual Centers (P-Centers). For studies investigating the P-center of musical sounds, see Gordon, "The Perceptual Attack Time of Musical Tones"; Wright, "The Shape of an Instant"; Danielsen et al., "Where Is the Beat in That Note?"; London et al., "A Comparison of Methods for Investigating the Perceptual Center of Musical Sounds."

[35] Gordon, "The Perceptual Attack Time of Musical Tones"; Wright, "The Shape of an Instant"; Danielsen et al., "Where Is the Beat in That Note?"; London et al., "A Comparison of Methods for Investigating the Perceptual Center of Musical Sounds."

Several of the musicians also point to the role of dynamics and frequency content in producing a timing feel. Sounds with a dark timbre and/or low pitch, in particular, tend to be heard as late or laid back. Dynamics is also stressed, in particular by drummer Ola Øverby. Although the role of relative intensity and frequency content in the perception of microtiming is not well documented, Câmara and colleagues found that early timing on the bass tends to involve higher relative intensity, and laid-back timing on the guitar means making a darker sound (with a lower spectral centroid).[36] Similarly, Danielsen and colleagues found a systematic relationship between high and low frequency ranges in musical sounds and perceived early and late timing, respectively.[37]

Regarding the perceived timing of compound sounds, drummer Ola Øverby experiences compound sounds where both sounds have comparatively hard (that is, fast) attacks, as friction. In his view, people have a greater tolerance for deviation in timing between sounds that are further apart in frequency. Auditory stream segregation is probably the reason why we tolerate and register, respectively, the aforementioned discrepancies.[38] It would appear that we group two sounds that are similar in frequency and timbre (hi-hat and lightly struck snare drum, for example) into one stream, whereas we group two sounds that belong to different frequency ranges (hi-hat and kick drum, for example) into separate streams. In turn, asynchronies in timing within a single stream come across as more intrusive or responsible for friction than asynchronies across different streams.

Overall, the consensus among our informants is that experienced (and actual) timing concerns much more than changes in the temporal placement of sounds. The whole feeling of the timing as regards both position and flexibility (the "beat bin") is susceptible to variations in attack shape, timbre, and dynamics—that is, to changes in the sonic features of the sound.

[36] Câmara et al., "Effects of Instructed Timing."
[37] Danielsen et al., "Where Is the Beat in That Note?"
[38] Bregman, *Auditory Stream Segregation*.

ANALYTICAL EXAMPLES

Methods

We will now take a closer look at two recordings by our interviewees. The aim of the analyses is to zoom in on actual examples of how interaction between sonic features and perceived microtiming manifests in practice. We wanted examples that represented quite different jazz-related groove performances and confined the number of songs to two to be able to go into more depth in the analyses. After the interviews, we thus asked saxophone player Morten Halle and Sofie Tollefsbøl, vocalist and band leader of the band Fieh, to select one song that they felt was relevant to the topics that came up in the interview sections. Guided by the musicians' comments on their own songs, the examples represent two different substyles of contemporary jazz: the Halle song is a lyrical Latin-inspired jazz ballad for saxophone and piano, while the Fieh song is a groove-oriented neo-soul track with vocals, backing vocals, brass, and a full rhythm section. Our center of interest was the way in which the feel of the pulse is shaped, focusing in the first song (Halle) on variation in attack shapes, and in the second (Fieh) on the compound beats of the chorus.

The Breathing Pulse in Halle and Morena: "Mambo"

"Mambo" is a song on Morten Halle and pianist Carlo Morena's duo album *Altopiano*, released in 2014. This acoustic saxophone and piano duo is a fitting example of what Halle refers to as a "looser" live jazz format. Halle describes the pulse in this song as able to "breathe" while still retaining the feeling of a pace and a beat. The focus of this analysis is to investigate the ways in which interactions between sonic features and microtiming generate the experience of a "breathing pulse."

"Mambo" starts with a very loose time feel where the saxophone plays melodic legato phrases with soft attacks, accompanied by clustered chords played by plucking the strings of the piano. The snapping and hammering on the piano strings form a percussive texture in contrast to the softer saxophone tones, but neither of these musical elements indicates a pulse. In what might be described as a call and response soundscape, the saxophone creates a rubato feel with its many dynamic variations, while the piano string clusters contribute a more ambient layer. At :53, however, the piano establishes a pulse via a bass ostinato (in what is clearly 4/4) that underpins the song's lead melody. Beat one is played as a staccato eighth note—that is, with a very short and pronounced delivery—followed by another eighth note on the offbeat of the second beat and a ringing

half note on the third beat. In contrast to the rubato sax intro, this section is overall characterized by harder attacks (see figure 1).

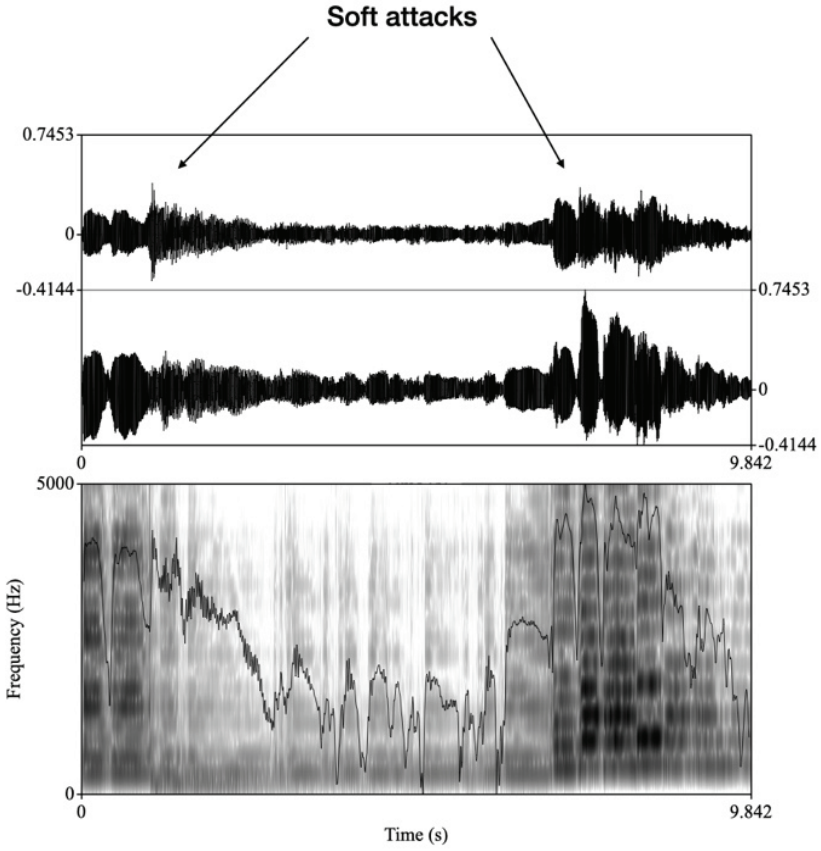

Figure 1a. Waveform (amplitude) and spectrogram of "rounded" sounds with soft attacks in the rubato sax intro (0:04–0:14) of the song "Mambo" by Halle and Morena (made in Praat, v. 6.1). Intensity curve in spectrogram in black.

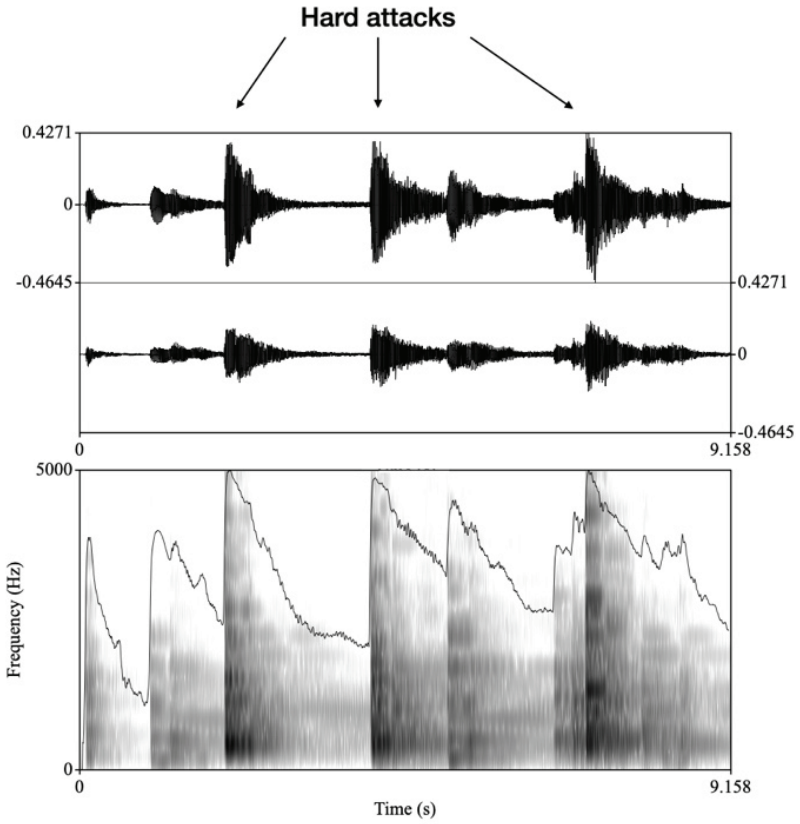

Figure 1b. Waveform (amplitude) and spectrogram of hard, percussive attacks in the piano comp (0:54–1:04) of the song "Mambo" by Halle and Morena (made in Praat, v. 6.1). Intensity curve in spectrogram in black.

When the bass ostinato in the piano begins it establishes a feeling of pulse, but there are nuances in the relation between sound and timing that contribute to this pulse having a "breathing" character. The phrasing of the melody played in unison by Halle and Morena is key here. The melody starts with an accentuated eighth note on the offbeat of the one and then continues with a more legato phrase. Whereas the first notes of the melody suggest the beat more directly with clearly articulated, harder attacks, the continuation of the melodic line is made looser through sustained saxophone pitches and softer, longer sounds in the piano. From beat three onwards many onsets are played with a crescendo with lots of air in the saxophone. The dynamic variation and the hard versus soft attacks result in slightly different microrhythmic feels, from jumpy and "pushed" to smooth and relaxed (see figure 2).

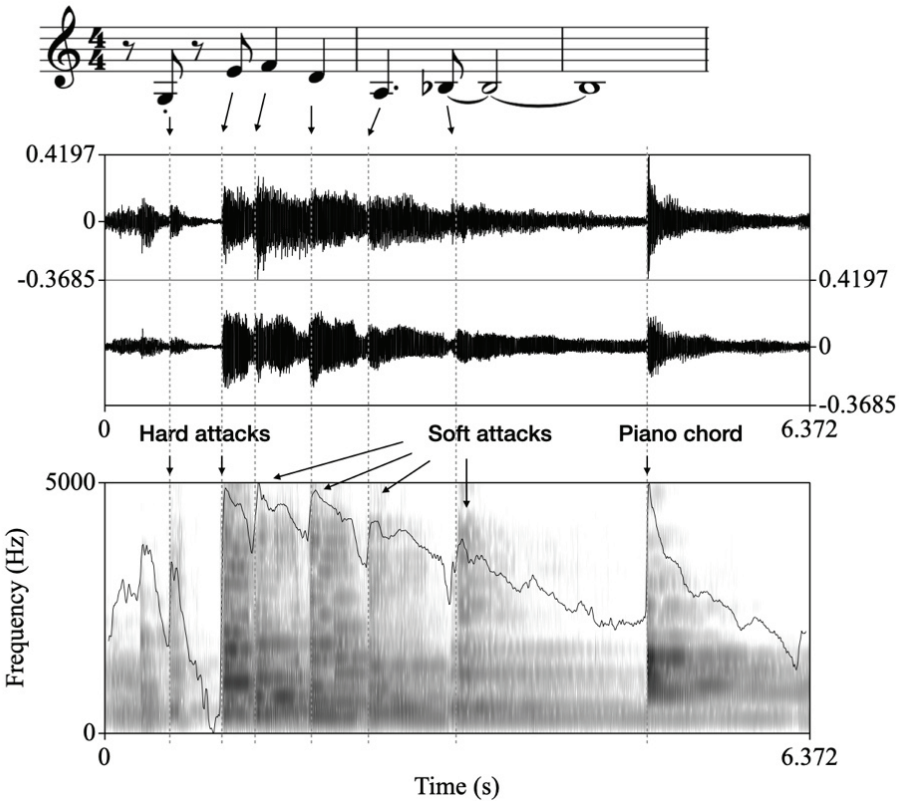

Figure 2. Transcription, waveform (amplitude) and spectrogram of the first bars of the melody theme played in unison by sax and piano (1:10–1:16) of the song "Mambo" by Halle and Morena (made in Praat, v. 6.1). Note onsets indicated by dotted vertical lines. Beat duration approx. 515 milliseconds. Intensity curve in spectrogram in black.

The lead melody continues with a run of falling arpeggios that ends on a long note lasting two bars, after which the pulse needs to be reestablished. This happens as the melody is played a second time around, but this time Halle plays the saxophone lead one octave higher than the piano. With the octave leap comes a natural rise in intensity, resulting from the effort required to play in this register on the saxophone. As Bregman observes, intensity affects the grouping within a stream, and the listener's attention will be drawn toward the sounds that suddenly increase in intensity in relation to the other sounds in the same stream.[39]

In his interview, drummer Ola Øverby points to how dynamic changes within a sequence of notes, and especially a dynamic *rise*, impact the perceived timing

[39] Ibid.

relationships. This effect surfaces clearly when Halle starts his saxophone improvisation at 2:40. After a few trills, he plays a dynamic phrase that increases in both volume and pitch, then falls away again. Commenting on the track, Halle notes that he tries to articulate how the pulse is shaped with the first notes of the first phrase: "The first eighth note [at 2:45] is very short, and I hear the start of the phrase as quite on top of the beat, but it fades out after a short while and moves into some kind of triplet, which is, in my experience [of it], both reduced in volume and letting go of the beat." At 2:54 Halle starts an ascending triplet-based phrase on the offbeat, the tones of which share a generally soft onset save for a hard tone in the middle of the phrase that he plays louder as well. The soft notes signal the shape of the pulse and lends a loose sense of timing to the phrase as a whole.

He concludes his commentary by commenting explicitly on how manipulating sonic features contributes to microtiming: "In addition to trying to hit early or late, of course, I would use volume and articulation. More volume and a heavy but not very hard attack will make a 'one' heavier and more on/behind the beat even though the temporal location might be exactly the same [as a hard-attack sound with less volume that is perceived as early]. And articulating the offbeat in a line of eighth notes with more volume than the notes that hit on the beat would produce a feeling of pushing the beat even though the notes in fact hit at the same place."[40]

To sum up, the variation in articulation between sounds with soft and hard attacks is an important aspect of this song's characteristic microrhythmic feel of pull and push. Consequently, it does not provide clear—or "absolute," in Halle's words—positioning of beats but instead allows the pulse to "breathe." This breathing character, which is an important aspect of the song for Halle, is a result of the song's various sound shapes, a general openness regarding exact timing, and the choices of dynamics and other forms of articulation. Halle confirms that he and Moreno intended to manipulate the shape and positioning of beats quite a lot in "Mambo" by exploiting and toying with the link between articulation and timing.

[40] In terms of his saxophone, Halle points out that, to play "pushed," he uses the tongue to achieve a clear onset of the tone, whereas he plays more laid back by "fading in" the tone with air alone.

Shaping Pulse in Fieh: "Samurai/When the Summer is Through"

Fieh is a seven-piece band that explores jazz, soul, funk, hip-hop, and R&B in their original music. As a second analytical example, we will discuss their song "Samurai/When the Summer is Through" from their debut album *Cold Water Burning Skin* (2019). We focus on the compound beats—that is, beats that are articulated by more than one source—of the chorus and in particular on how sound shapes and frequency content affect stream segregation and, consequently, the perceptual tolerance for beat asynchronies between rhythmic layers in the groove. Fieh's instrumentation, consisting of drums, bass, keys, guitar, trumpet, and vocals, gives this music a rich and complex sound base that is ideal for zooming in on the relations between frequency ranges, stream segregation, and the perception of pulse.

The song, set in the key of G# minor, starts with a synthesizer playing a sequence of major thirds moving diatonically from the fifth to the tonic while holding a D# as a drone on top of the chords to form this chord sequence: D# – Emaj7 – D#m/F# – G# (see figure 3).[41] The synthesizer uses a long, gradual attack and starts off with a closed sound that gradually opens up its higher frequencies with a filtering effect. In addition, the synthesizer features a "gliding" onset, so the attack of the sound is not very precisely defined. With its combination of long notes, long attack, and audio effects, the synthesizer element present here evokes what many of our informants describe as a soft and long sound, which they in turn tend to perceive as laid back. In fact, Ola Øverby uses the attack and release parameters of a synthesizer as examples of what he understands to be laidback sounds—that is, sounds that become apparent only a little while after their onset. However, the synthesizer is not the only element present in this intro—there is a cymbal playing a syncopated sixteenth-note pattern, and finger snaps accentuate beats two and four (see figure 3). The precision of the harder and faster sounds of these percussive elements establishes a clear pulse that also makes the more diffuse perceived timing of the synthesizer sound clearer.

[41] Even though the chord sequence and tonality here does not necessarily indicate a key of G# minor, that key is clearly established following the four introductory bars, when the chords alternate between a G#m and a F# chord. The transcription is notated in the key of G# minor because the tonality of the introduction (and chorus) is interpreted as a harmonic variation within the G# minor key (a passing modulation).

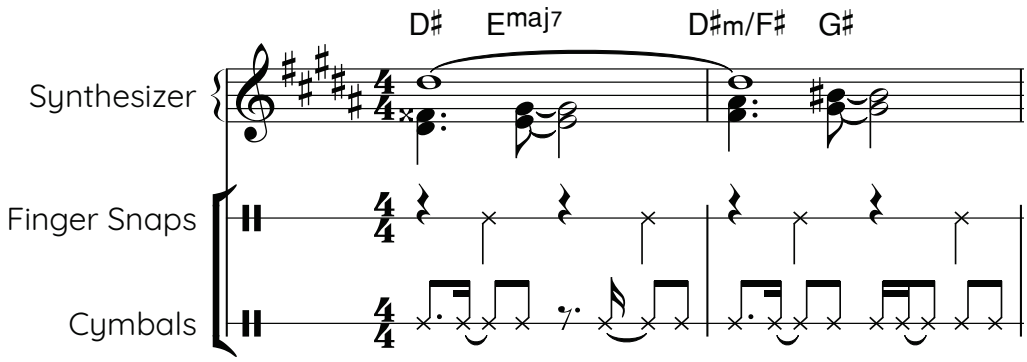

Figure 3. First two bars of "Samurai/When the Summer is Through." The synthesizer supplies longer chords played with a soft sound and long attack, while the finger snaps and cymbals provide hard sounds with a more precise timing reference.

After a verse that continues the introduction's pulse with a clear backbeat, the chorus section abandons the pulse. Here, the song reverts to the harmonic pattern from the introduction and the synthesizer element from this section returns as well, this time with its filtering effect turned further up. In the rhythm section, the stable backbeat gives way to a drum part that alternates between triplets and eighth notes on the hi-hat, as well as snare strikes on beat three and the offbeat of beat three in every other measure. The bass replaces its rhythmic eighth-note ostinato with long tones that reinforce the rhythm of the synthesizer. The guitar and Rhodes keyboard are panned hard to the left and right, respectively, but even though they share rather pronounced attacks, they are mixed too low for their percussive qualities to penetrate. On top of this, the vocals alternate between shorter, more staccato notes and longer melodic ones while presenting a melody that is phrased considerably behind the beat and more and more so as the two-bar phrase proceeds, ending up with the last syllable ("too") being placed more than a 16th note behind (while structurally still belonging to the beat, see figure 4). However, this last syllable can also be heard as "locking in" with the meter by forming a syncopation to the snare stroke on three-and. This structural ambiguity may be the key to the mesmerizing effect of this melodic phrasing.

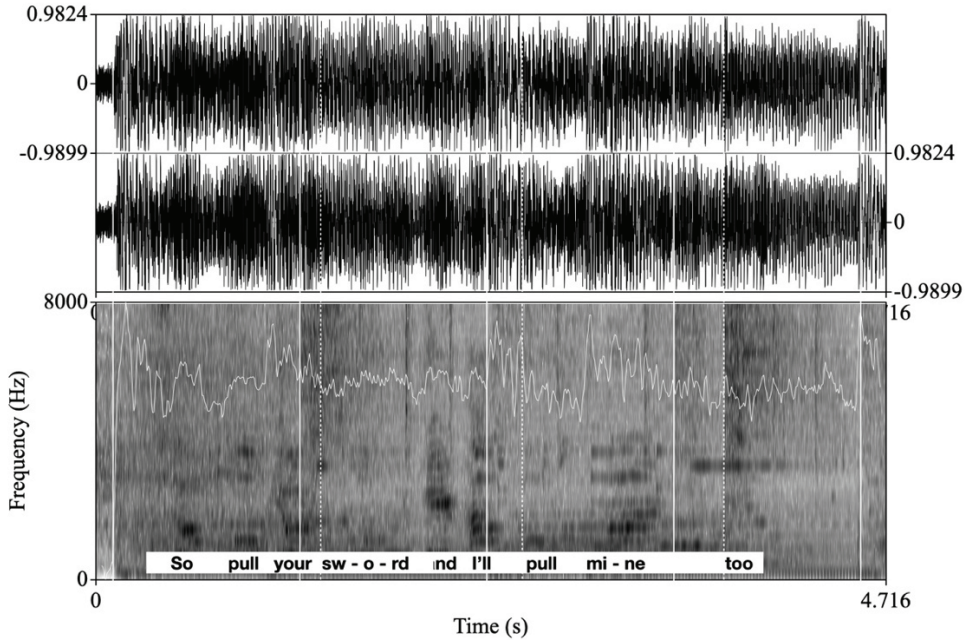

Figure 4. Waveform (amplitude) and spectrogram of the first two bars of chorus 1 (1:10–1:15) of Fieh's "Samurai" (made in Praat, v. 6.1). White vertical lines indicate an isochronous grid of quarter notes (beats one and five are aligned with the kick drum's onset). Dotted vertical lines indicate the lead vocal's increasingly delayed positioning of beat-related syllables. Intensity curve in spectrogram in white.

Consequently, what we hear in the chorus is a composite of complex sounds, none of which function as a tight pulse reference—contrasting sharply with the backbeat rhythm that dominated previous sections of the song. Regarding the bass's switch from laying down the pulse together with the drums to playing longer notes together with the synth, vocalist Sofie Tollefsbøl says that this flexibility is not unusual for Fieh, and that the sense of pulse could be anywhere among the musicians at any time. In other words, the more marked sounds of the drums and vocals in the chorus could be heard to take over some of the responsibility for sustaining a pulse from the bass, though even here, variations in accentuation and temporal placement of sounds and accents blur the boundaries. There are many complex sounds and streams, but none of them point to exactly where the pulse is in the chorus. That said, we still hear a regular pulse, but the beat bin is considerably widened, affording more loose synchronization between instruments and more extreme flexibility in the melodic phrasing.

As Bregman has illustrated, differences in intensity, timbre and frequency range, and space will sort sounds for the listener into different streams.[42] Relatively notable discrepancies that would be perceived as intrusive within the same stream are more likely to be tolerated across streams. Along those lines, the various musical elements of the chorus might be "working together on the same hit" (as Øverby describes this phenomenon) because they do not interfere with one another in terms of their sonic qualities. The drums and the vocals, for example, are heard as belonging to separate streams and this makes the substantial asynchronies between their respective beat locations "perceptually acceptable." All in all, the chorus section presents as "systematic chaos," the pulse of which only emerges through a loose synchronization of the different musical streams into wide beat bins.

This systematic chaos evokes Mats Johansson's concept of *rhythmic tolerance*. In Johansson's study of Scandinavian folk music, he finds that the rhythmic framework itself—the bars and beats—may bend or morph in terms of its localized durations from one part of a performance to another without any compromising of the initiated listener's experience of its overall flow, tempo, and groove. This intentionally flexible groove "addresses the musician's ability to shape melodic-rhythmic phrases within a malleable temporal framework, so that the same rhythmic style may manifest itself as a range of different patterns of durations across (and within) tunes."[43] This does *not* imply that one experiences this music as either temporally varied or unstable. Similarly, the chorus of "Samurai" also establishes a certain level of tolerance for rhythmic flexibility in the listener, so that one experiences the pulse as elusive but not *off*. If nothing else, the complexity of the musical elements and compound sounds in "Samurai" allows for many possible streams. When the verse's percussive sounds surrender to the chorus's composite texture of compound sounds and multiple pulse references, we find ourselves with a much richer sense of pulse. Concepts such as beat bins, rhythmic tolerance and stream segregation help to explain why we continue to experience a continuity in flow and groove even when several pulse references and significant durational flexibility are present.

[42] Bregman, *Auditory Scene Analysis*, 644.
[43] Johansson, "The Concept of Rhythmic Tolerance", 77.

CONCLUSION AND IMPLICATIONS

The purpose of this study was to investigate whether jazz musicians intentionally use microrhythmic aspects other than relative temporal positions, such as the character of the attack, relative intensity, and/or timbre, to shape the micro level of rhythm in their performances. We interviewed five musicians from different jazz subgenres with different areas of instrumental expertise and found that they were, as expected, concerned with timing and the interaction with other musicians in their performances. They were also aware of the effects that sound shape, relative intensity, timbre, and relative frequency range have on perceived timing and made intentional use of such parameters in their performances via their playing technique as well as the manipulation of the general quality of sound of their instruments.

When these musicians talk about how various sound features affect timing, they often describe softer and longer sounds as expressing a "breathing," "floating," or "living" beat or pulse and percussive and shorter sounds as being "precise," "absolute," or "mathematically correct" in their nature. In other words, our informants explicitly state that hard sounds (or those with a fast attack) tend to produce a tight or rigid timing feel, whereas softer sounds (or those with a slow attack) allow for a less defined or more flexible temporal position. Hard and soft sounds are also seen as opposites regarding their perceived position in relation to a beat reference and are experienced as slightly pushed and laid back, respectively. Moreover, when hard and soft attacks are played by different instruments at the same time, these musicians find that the fast-attack sounds usually define the temporal location of this compound event. Our interviewees' observations align with results from empirical research into how acoustic factors influence both the perceived timing position—that is, the perceptual center where the rhythmic event is perceived to occur—and the timing precision—that is, the flexibility or width of the beat bin of the musical sound.

In this study, we also analyzed two recorded songs to explore the effects of interactions between sonic features and perceived timing–sound interactions in an actual musical context. In Halle and Morena's "Mambo," variation in the articulation of soft and hard sounds creates a microrhythmic pull and push that comes to characterize this song as a whole. Along with the performance's varying dynamics, this strategic articulation makes the song appear to be "breathing." In Fieh's "Samurai/When the Summer Is Through," the complex weave of musical elements in the chorus—none of which give exact indications of where the pulse is located at the micro level—and the various auditory streams they represent shapes the listener's perception of wide beat bins and timing flexibility. Multiple and vague pulse references serve to expand our rhythmic tolerance and imply a

pulse that challenges but never disrupts our experience of continuity in the song's flow and groove.

Overall, then, the fact that a sound's quality of attack influences its perceived timing and that of other sounds with which it is combined manifests itself in both the musicians' discourse and their aesthetic practice. Our interviewees describe themselves as generally very aware of the ways in which they, through their playing technique, can use the shape of the attack as well as relative intensity, timbre and frequency range to shape the overall timing feel of a performance. They also acknowledge that different instruments have correspondingly different abilities to accomplish this—voice and saxophone, for example, are very flexible with regard to the sound shapes they can produce, whereas drums and plucked instruments are more limited. When such instruments interact and especially coincide, the harder sound will prevail in terms of the timing feel of the passage.

This study demonstrates musicians' advanced and detailed appreciation for the possibilities in the interaction between temporal and sonic features at the micro level of rhythm and sheds new light on practicing jazz musicians' use of microrhythmic aspects other than relative temporal positions to shape the perceived microtiming and feel of a performance. It demonstrates the need to move related research beyond the temporal domain, and to cultivate a more holistic approach to what constitutes groove in jazz and related genres. In future projects, it would be interesting to investigate in more detail the extent to which the interactions between sonic features and perceived microtiming identified in this study are specific to the instruments and sub-styles examined here or also typical of other instruments and sub-styles in jazz.

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