Speed in music
McGowan, E.L.

Speed in Music

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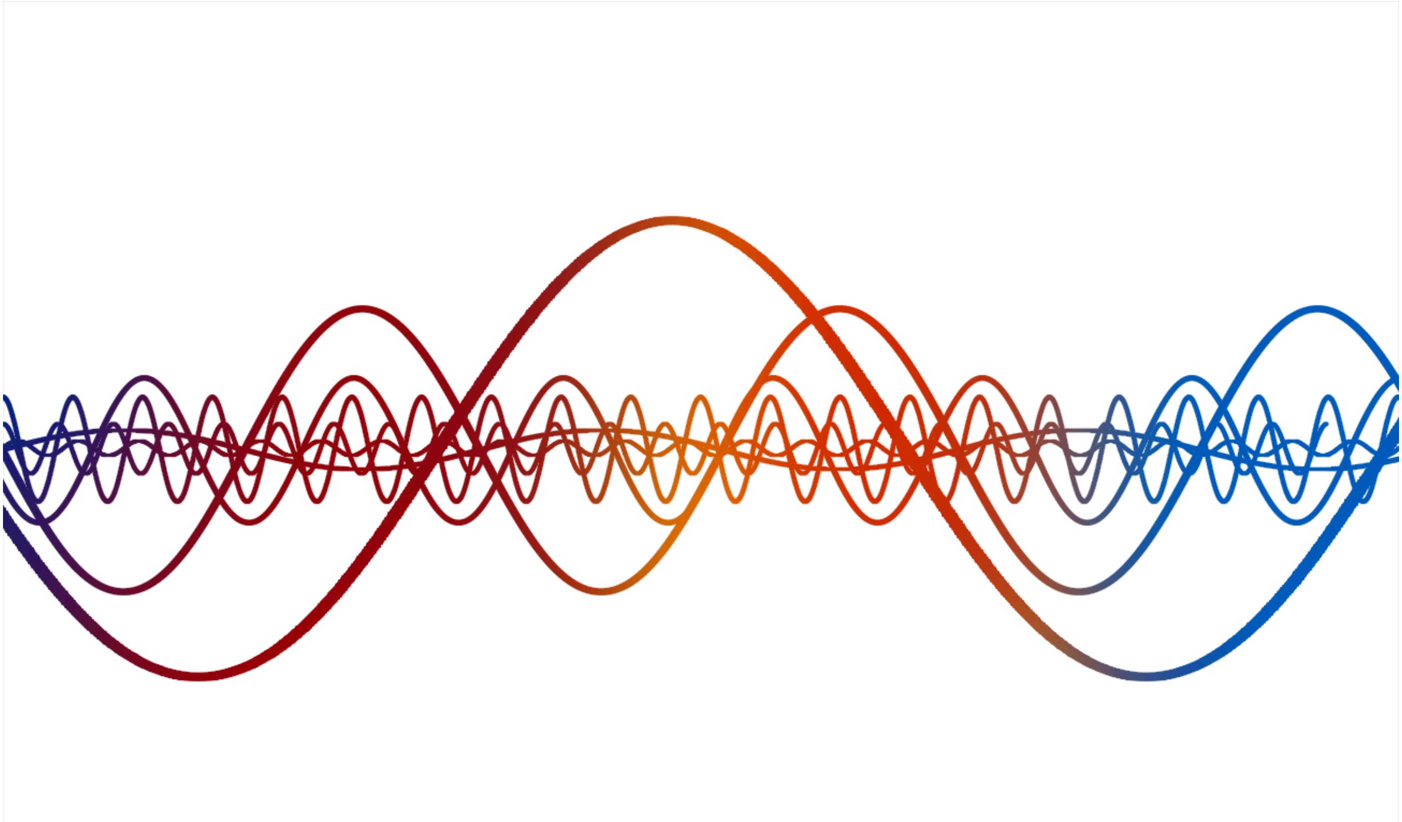
Speed in Music



Ned McGowan

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Chapter 1: Introduction

1.1 Stories

Story #1

1998, Rotterdam, Netherlands
Gaudeamus Interpreters Award competition

As a 28-year-old flutist who had moved to the Netherlands four years earlier to specialize in new music, I saw this competition as the pinnacle of my aspirations, and the center of my artistic world. I had diligently prepared over sixty minutes of demanding 20th-century repertoire for this moment, including works by Salvatore Sciarrino, Theo Loevendie, and myself. Yet it was Brian Ferneyhough's *Carceri d'Invenzione IIb* that consumed the lion's share of my focus. Over more than a year, I dedicated daily hours to mastering its nine dense pages filled with microtones, irrational meters,[1] and intricate 128th note quintuplet rhythms. After prolonged engagement with the score, I reached a point where performing it from memory seemed within grasp.

Unsurprisingly, the judges selected this formidable piece for me to perform in the first round. Pushing the music stand aside, I managed, despite significant nerves, to complete the piece without memory lapses. My joy at progressing to the second round, however, was brief - I did not advance further.

Determined to learn from the experience, I approached one of the judges, percussionist Steven Schick, for feedback. His critique was insightful: when performing Ferneyhough by memory, one must guard against unintentionally quantizing rhythms - reducing a nuanced narrative rich with multiple tempi and complex tuplets into just a few simplified speeds.

Schick's comment sparked numerous questions for me. Chief among them was how to authentically render the diverse array of speeds indicated in the score. Had my method - merging bar-specific beat patterns with approximations of tuplet speeds - fallen short? Furthermore, some passages called for speeds beyond my technical abilities, turning precisely notated tempi into sections performed only "as fast as possible." Had I inadvertently grouped too many segments into this simplified approach, thereby reducing rhythmic complexity? Additionally, I wondered if memorizing the piece, rather than reading directly from the score, contributed to this unintended rhythmic simplification. Certainly, performance anxiety had accelerated my playing and introduced considerable physical tension. This recognition raised another crucial question: what role does physical embodiment play in producing and controlling speed during performance?

These inquiries began to ferment, eventually igniting my exploration of speed in music and forming the core theme of this dissertation.

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[1] The term irrational time signatures, also called odd-factored time signatures (Wheatley, 2024), refers to meters whose denominator is not a power of two (that is, not 2^n; e.g., 3, 5, 6, 7, 9, 10, 12, …).

Story #2

1993, San Francisco, United States
Lesson with flutist Tim Day

I was playing a passage from a piece consisting of straight 16th notes, but there was one particularly challenging part with some tricky third-register fingering combinations that I consistently struggled with, often flubbing or missing notes entirely. Day's suggestion was to slow down at that part, making sure I hit all the notes. After doing so, he pointed out the result: the passage sounded like even 16ths, smoothly played without any perceptible slowing down, yet correctly executed. This offered a clear demonstration that perceived speed is situated, shaped by attention, bodily control, and the felt pressure of technical difficulty.

1.2 Research Topic and Research Questions

Both these stories underscore the elusive and fluid nature of speed, demonstrating how its perception can differ significantly between performer and listener, and how easily the complexity and subtlety of speed can be unintentionally simplified. They highlight the body's significant yet often overlooked role in managing speed during performance, the different outcomes of playing from memory versus reading from a score, and the impact of emotions on our temporal perception. Collectively, they show that the perception of speed depends on many factors, including bodily technique, memory and notation, attention, and emotion. For that reason, musical speed is variable across situations and easily reduced to a single, oversimplified parameter."

This realization contrasted sharply with my earlier rhythmic training, where rhythm was something concrete and predictable, neatly defined by notations, metronomes, or the steady reliability of a groove. My foundational experiences included:

> - Earliest music lessons with flutist Gary Stotz, providing a strong rhythmic foundation through regular practice with the Tap Master[2] rhythmic training machine. He also started teaching me to improvise, fostering a creative exploration of rhythm.
>
> - Formal classical music studies combined with immersion in jazz and groove-based popular music.
>
> - College studies at the Cleveland Institute of Music, involving dedicated practice and mastery of embodied Dalcroze Eurythmics exercises under the guidance of David Brown, enhancing my physical understanding of rhythm and musical timing.
>
> - Studies in the Netherlands, initiating an exploration of rhythmic techniques from Indian Carnatic Classical music, which eventually led to the development of my *Advanced Rhythm and Pulse* course at the Utrecht Conservatory.

Schick's and Day's feedback stayed with me. Reflecting on these experiences, I came to see musical time as a rich and intricate web, encompassing a multitude of topics such as notation, accurate learning, integration in performance, rhythmic complexity, subjective interpretations, differences in tempo perception between performers and listeners, and a wide array of expressive nuances. In the years following the competition mentioned above, I expanded my musical activities to focus principally on composition, actively engaging with the diverse aspects of rhythm and time. Looking back over several decades of compositions and musical experiences, I recognized that all these varied rhythmic explorations were connected by a concern that emerged as a recurring dimension: speed. Ultimately, my artistic journey has consistently revolved around understanding and expressing the rich and varied ways in which speed can manifest and operate in music, leading to the central inquiry driving this dissertation: *What is speed in music, and how can I explore it creatively and practically within my artistic practice?*

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[2] The TAP Master rhythm training system functioned by synchronizing instructional cassette tapes with a hardware console equipped with a tactile tapping pad. Students would tap along to rhythmic patterns heard on the tape, while the machine electronically compared their performance against the "correct" timing encoded on a separate, inaudible channel. It provided immediate visual feedback through lights or counters, allowing students to self-correct in real time as they progressed from basic pulses to complex syncopations.

In posing this two-part question, it is important to note that *speed* will not be treated here as a synonym for related terms such as *tempo*, *rhythm*, or *time*. While those concepts will be addressed and often overlap with speed, they name different dimensions of musical temporality. *Tempo* refers to a regulated pulse; *rhythm* to the patterned organization of durations; and *time* to a much broader field of musical and experiential temporality. *Speed*, as I develop it in this dissertation, refers more specifically to the perceived and enacted rate of musical events. Rather than a single parameter, it is an emergent composite of several simultaneous rates, including pulse, event density, grouping, and rates of musical change. In this sense, perceived speed functions as an experiential resultant of that multiplicity, and it can diverge from tempo markings, rhythmic grids.

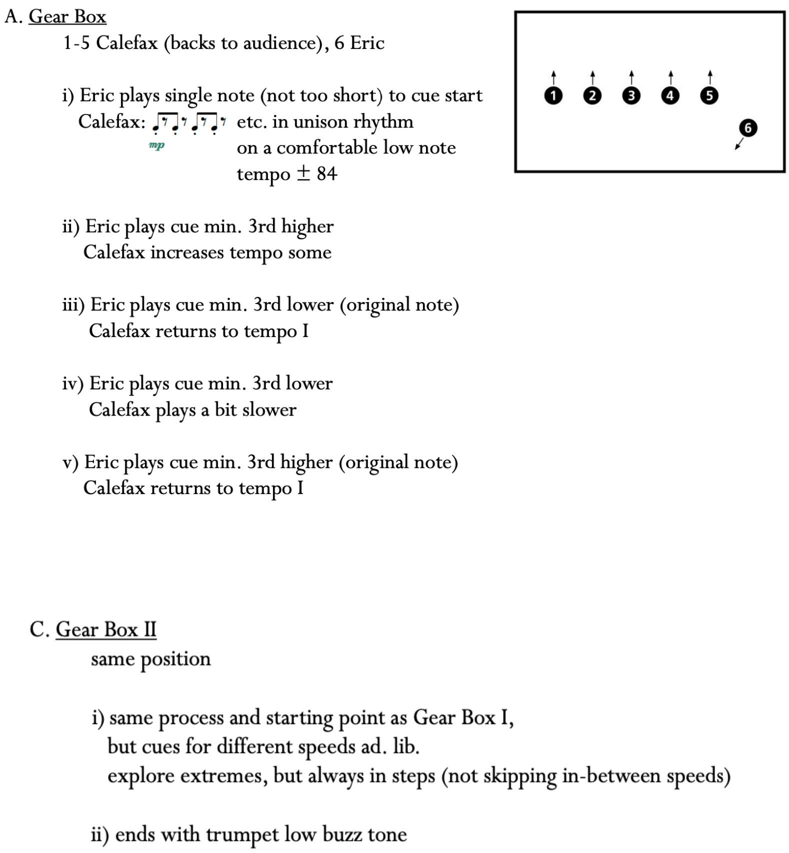
In the next section I will present some examples of speed in my music.

1.3 Speed in My Music

Here are some brief examples from my works that employ different techniques and produce diverse expressive results, expressing how I imagine the possibilities of speed in music. Unless indicated otherwise, the compositions discussed in this dissertation are my own, and any instances of co composition are explicitly noted. Each example highlights a distinct approach to speed, among many approaches which will be further examined in this thesis.

1.3.1 Shifts in Speed

Section "Gear Box", movement 4 "n'est-ce pas spatial?" from *six pièces mécaniques* (2012) for reed quintet and trumpet



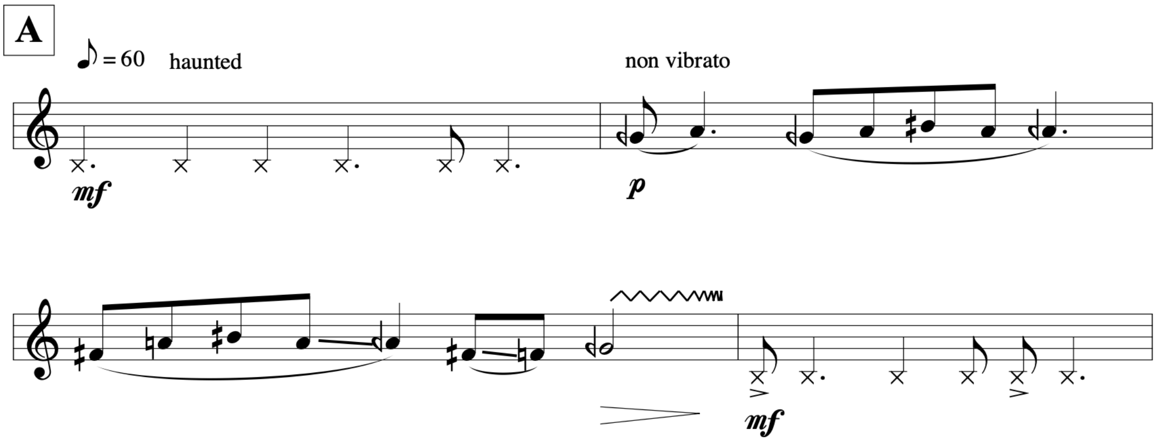
Example 1.1 "Gear Box", score excerpt. Video excerpt.[3]

In *Gear Box* I explored changes of speed in repeated notes, using a simple cueing system in which the trumpeter accelerates and decelerates to produce distinct characters at different rates. The part explicitly invites an exploration of the extremes of both slow and fast tempos. While the mechanism is simple, the results can be surprising. At slower tempi, the increased spacing between notes heightens the sense of anticipation before each onset. As the speeds become faster and faster, at 3 minutes and 1 second into the performance, the reed players transition from performing clearly articulated individual notes to employing a flutter tongue technique, producing a rapid, buzzing effect that significantly alters the texture and perceived speed of the music.

[3] The performers of my works are cited in References.

1.3.2 Slow Speed

Moonrise, for solo flute (1998)



Example 1.2. *Moonrise*, score and audio excerpt.

A slow 8th note tempo allows for precise microtones to be clearly perceived. Because key clicks are brief transients and the notated durations are long, a clear contrast arises between each short click and the silence that follows before the next one, emphasizing the intricate relationship between note length, silence, and the articulated flow of time.

1.3.3 Fast Speed

Cycle Games 1, for vocal percussion (2019)

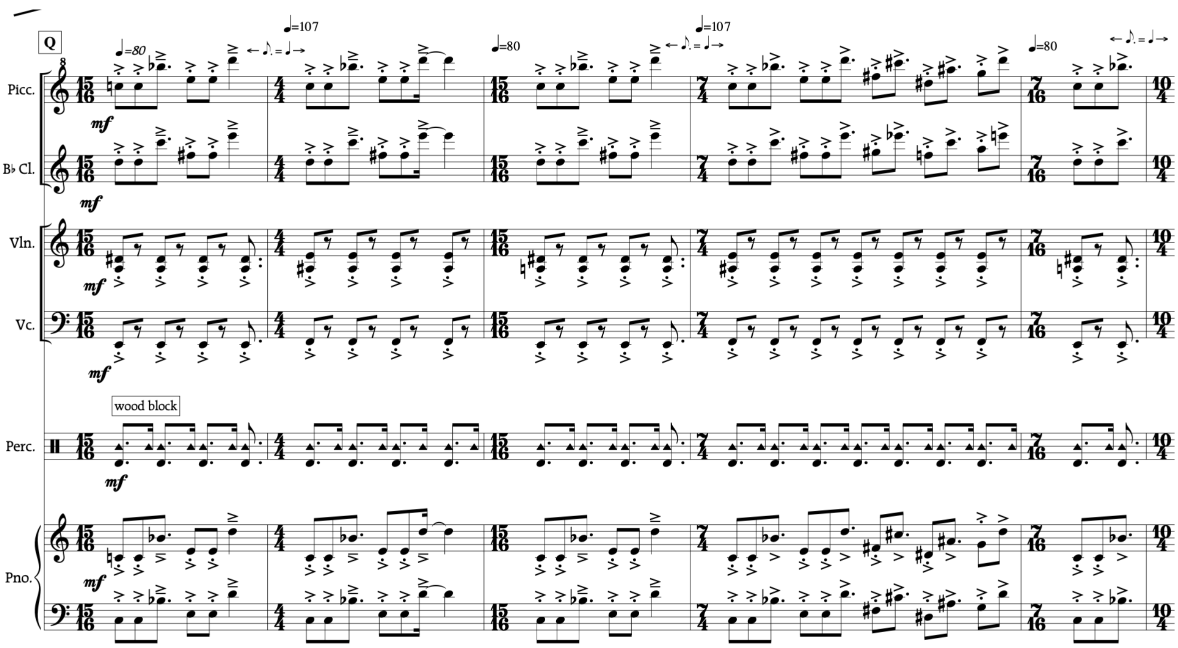
Example 1.3. *Cycle Games 1*, score and audio excerpt.

This example demonstrates vocal percussion woven into rapid rhythmic patterns, drawing on the narrative qualities typical in Indian percussion music that influenced this piece. The different vertical placements on the staff indicate motivic groupings rather than specific pitches or instruments. Both layered voices and unison approaches are explored. The rhythmic patterns and groupings change, while the tuplet remains consistent.

1.3.4 Changing Tempo

Garden of Iniquitous Creatures, for mixed sextet (2016)

Through metric modulation, a single motive is abruptly shifted into different speeds, creating instability and a deliberate sense of imbalance.



Example 1.4. *Garden of Iniquitous Creatures*, score and audio excerpt.

1.3.5 Rhythms and Theme of Different Speeds

Benson Town, for contrabass flute and mridangam (McGowan & Manjunath, 2016)

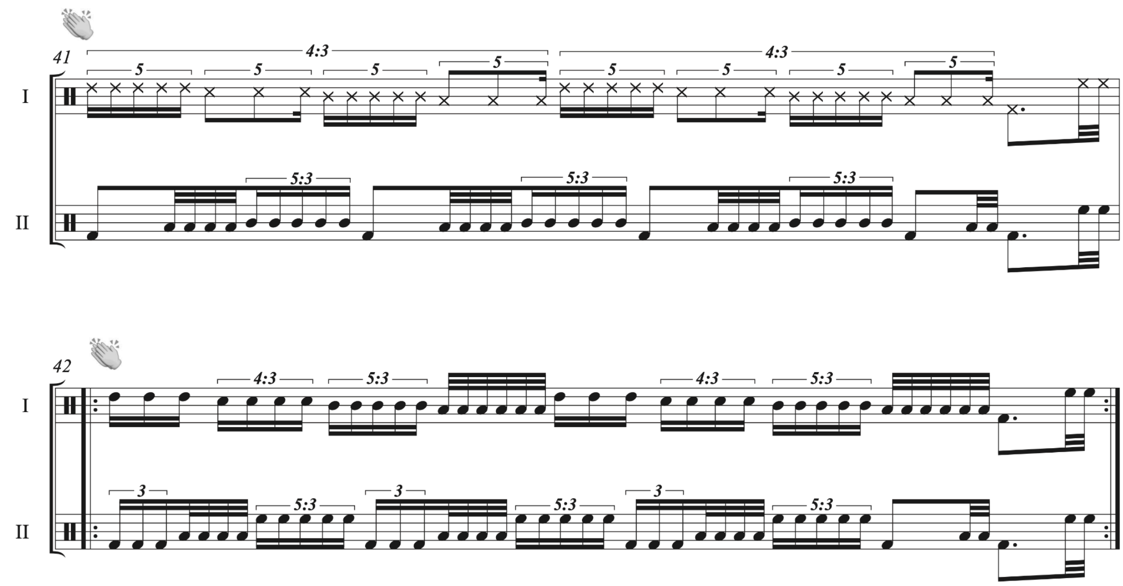
In *Benson Town*, composed in collaboration with percussionist B.C. Manjunath, the opening theme is comprised of four-note motives in rhythmic lengths of a 16th, an 8th, and a dotted 8th, separated by a single 8th note. For the second iteration, these note lengths are systematically halved, reflecting the mathematical precision characteristic of Carnatic rhythmic structures. This proportional manipulation, juxtaposing precise elongation with a doubling of speed, generates anticipation, surprise, and structural clarity.

Example 1.5. *Benson Town*, score and audio excerpt.

1.3.6 Use of Tuplets

Cycle Games 1, for vocal percussion (2019)

Both simple and nested tuplets create an intricate rhythmic dialogue, evoking simultaneous, overlapping conversations and creating layered speeds, where different lines move at different rates at the same time.

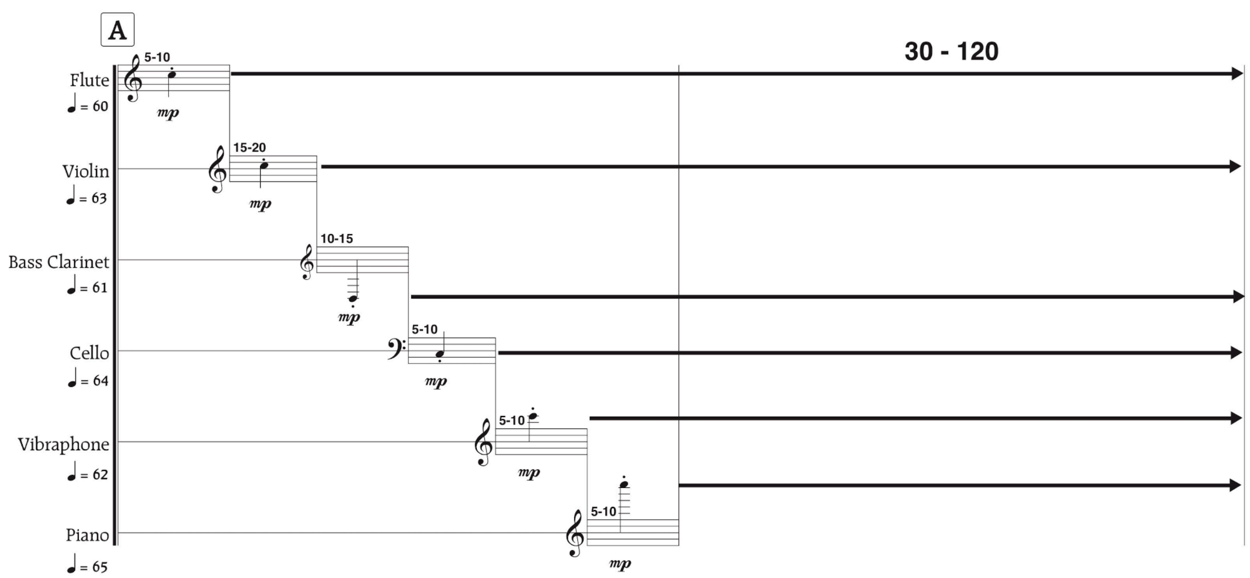


Example 1.6. *Cycle Games 1*, score and audio excerpt.

1.3.7 Polytempo

Sydney Polypulse, for mixed sextet (2019)

Each instrumentalist follows an individual tempo, creating textures of subtly transforming rhythmic relationships through simple repeated notes.



Example 1.7. *Sydney Polypulse*, score and audio excerpt.

1.3.8 Layered Speeds

Tools, for mixed quartet (2003), movement "Telescopic Ladder"

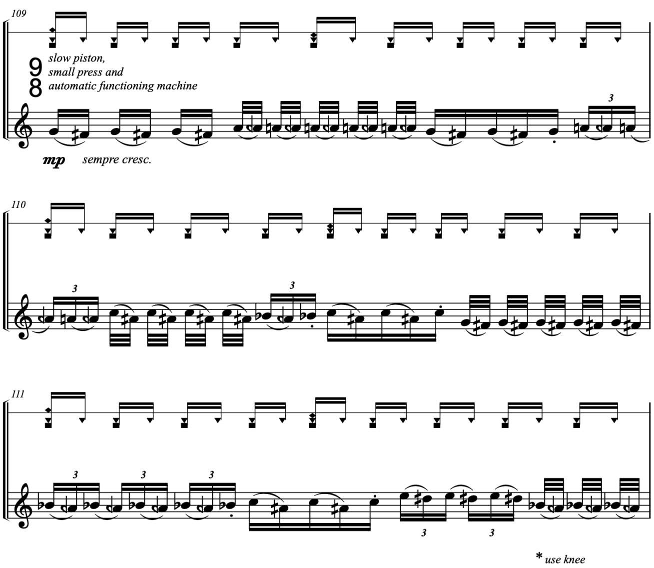
A temporal canon features four voices, each progressing at a 4:3 speed ratio to the previous voice, creating the impression of time compressing as the ensemble approaches unison.

Example 1.8. movement "Telescopic Ladder", score and audio excerpt.

1.3.9 Industrial Speeds

Workshop, for recorder and fixed media (2004)

The rhythms in the recorder part mimic machine-like regularity, executed as exactly as possible with minimal expressive microtiming. The more rigidly the onsets lock to an even grid, the more the music projects a single, machine-like speed, with the intended result of a steady, uniform sense of speed with no perceptible timing deviations.

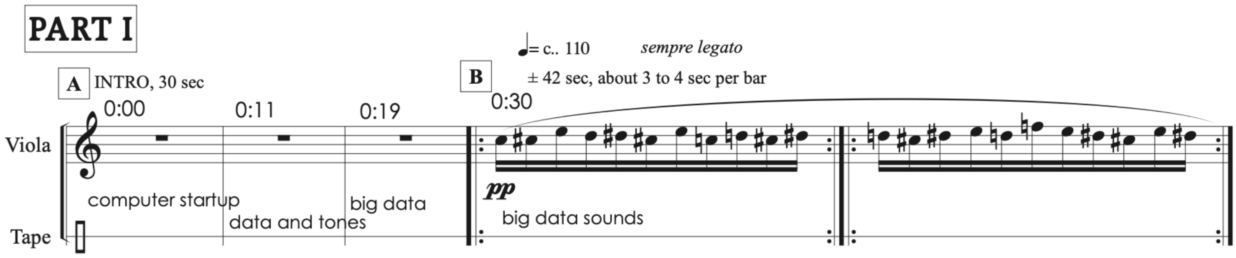


Example 1.9. *Workshop*, score and audio excerpt.

1.3.10 Electronic Speeds

Volt, for viola and fixed media (2015)

The tape part contrasts the rapid speeds of computer-generated sounds with slower human movements, reaching magnitudes even faster than the industrial machines in the example above.

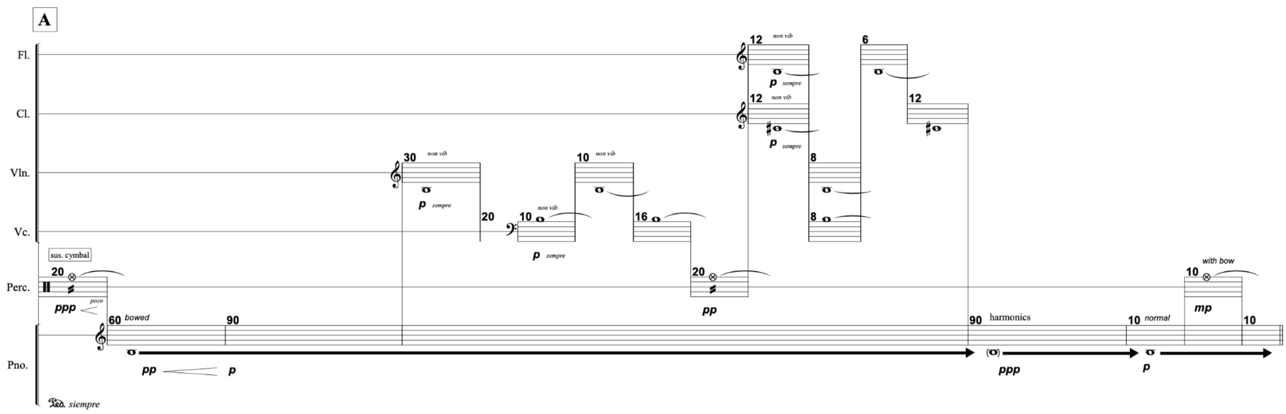


Example 1.10. *Volt*, score and audio excerpt.

1.3.11 No Speed

Sound Becomes Visible in the Form of Radiance, for mixed sextet (2010)

Durations are explicitly defined in seconds (above the staff at the left side of each bar), emphasizing subtle timbral shifts at glacially slow pacing. The first bowed note in the piano of two and a half minutes contains almost no development of sound save a slight crescendo. The intention from the outset was to “stop time” for the listener and remove any expectation for rapid events.



Example 1.11. *Sound Becomes Visible in the Form of Radiance*, score and audio excerpt.

Collectively, these examples reveal speed in music as multifaceted and nuanced, shaped profoundly by compositional techniques, interpretative choices, and diverse artistic intentions. In this dissertation, the term speed functions as a deliberate conceptual shorthand, drawing attention to this complex web of concepts and perceptions. Each piece demonstrates speed as integral to musical expression, beyond simple tempo measurements, engaging deeply with rhythmic, temporal, and perceptual dimensions.

1.4 Why Speed?

In order to understand the context and significance of speed in music, it is necessary to briefly zoom out to examine the broader topic of musical time. In this dissertation, I treat 'musical time' as an umbrella word that encompasses a complex web of subtopics, each carrying different meanings depending on their context. Duration, tempo, rhythm, timing, and speed can all be seen as different dimensions of this overarching term.

Time in Music

In practice, the word "time" has many meanings. For example, here are some uses specifically related to music:

- The "total time" of a piece is its duration.

- A "time signature" gives the length of a bar in beats.

- "Timing" usually refers to the exact placement of notes in performance, but could also refer to flow of the phrasing or proportional choices in the form.

- "Double time" means to play twice as fast.

- "Repeat that passage 4 times" means to play four iterations of it.

- "Time stretching or compression" in digital audio processing is to take a given duration of recorded audio and change it, resulting in its perceived speed also changing.

- "Real-time" processing means to apply effects or changes to a sound as it is being played.

- "Music of the time" refers to the musical style of a specific chronological period.

Across music theory, musicology, and performance studies, time has emerged as a central topic of inquiry, particularly from the mid-twentieth century onwards. In recent decades, scholars have increasingly treated musical time not just as a backdrop for events, but as a crucial dimension of musical experience and structure. For example, prominent music theorist Jonathan Kramer opened his book *The Time of Music* from 1988 by observing that musical time had not been widely recognized as an independent field of study (Kramer, 1988, p. 2). Just thirteen years later, composer and computer music researcher Curtis Roads proposed a detailed parsing of musical time in his book *Microsound* (Roads, 2001, p. 5), including a figure presenting "Time Scales in Music."

Understanding time in music involves exploring multiple perspectives across various academic disciplines. What follows is a concise, though not exhaustive overview of the ways in which various disciplines generate different understandings of musical time, including speed, duration, rhythm, and synchronization.

- Music Theory: Focuses on rhythmic structures, meter, tempo, and timing relationships within compositions.

- Performance Studies: Investigates how performers interpret and embody time, including microtiming, expressive timing, and synchronization.

- Cognitive Psychology: Explores perception of musical time, rhythm processing, memory, and temporal expectancy.

- Neuroscience: Examines neural mechanisms underlying rhythmic perception, temporal processing, and synchronization in the brain.

- Ethnomusicology: Considers cultural differences in (experiencing) musical temporality, including rhythm concepts, timing practices, and temporal frameworks in diverse musical traditions.

- Philosophy: Addresses conceptual and existential questions about musical temporality, time consciousness, and phenomenological experiences of musical duration.

- Physics and Acoustics: Analyses physical properties of sound, time-frequency relationships, duration, and temporal resolution.

- Composition: Studies compositional techniques that manipulate temporal perception, including speed, density, polyrhythms, and time dilation or compression.

- Computer Music and Technology: Explores digital representations and manipulations of musical time, including algorithmic composition, temporal modeling, granular level manipulation, and interactive systems.

- Sociology and Anthropology: Investigates how social contexts, rituals, and collective practices shape experiences of musical time and rhythmic coordination.

- Historical Musicology: Examines how concepts of musical time and rhythm have evolved historically, including changes in notation, temporal aesthetics, and performance practice.

- Ecological and Embodied Cognition: Looks at how the interaction between body, environment, and musical structures shapes temporal experience.

Time in music is fundamentally multidimensional, understood through diverse yet interconnected fields of study, and this overview provides a context from which to examine one particular aspect of musical temporality - speed.

Speed as an Underexamined Facet of Musical Time

Within the extensive literature on musical time, speed stands out as a fundamental dimension. Every piece of music embodies an approach to speed, implicitly or explicitly conveying something about its pacing, and listeners instinctively perceive passages along a spectrum of descriptors such as “fast,” “slow,” “rushed,” “relaxed,” “glacial” or “frenetic.” Although central to musical experience, speed has rarely been the primary focus of musicological inquiry. It is typically treated as a given parameter, such as tempo, rather than investigated as an integrated concept that combines compositional, performative, and theoretical perspectives. In what follows, I trace how speed is folded into neighboring discussions across music theory, performance research, and cognitive and scientific studies, before positioning my own practice based definition and framework.

A substantial body of work theorizes musical time without making speed a central, integrated concept. In the domain of meter and tempo, music theorist Justin London's *Hearing in Time* (2012) offers a foundational psychological account that foregrounds perceptual and cognitive constraints on metric entrainment rather than speed as such. From an embodied and phenomenological perspective, music theorist Mariusz Kozak's *Enacting Musical Time* (2020) describes musical time as enacted through bodily movement and interaction, again without isolating speed as a concept that cuts across composition, performance, and analysis. A broader disciplinary panorama appears in *The Oxford Handbook of Time in Music* (Doffman et al., 2021). Across its historical, analytical, cognitive, and ethnographic perspectives, questions that bear directly on speed are distributed across adjacent topics such as tempo and timing as embodied and cross-modal phenomena, rhythmic entrainment and beatmatching, musical timescales, and technological mediation such as the metronome and rhythmic quantization. The *Handbook* also approaches speed as a cultural condition, for example in discussions of musical time in a fast world or genres such as drum and bass, where rates of change and temporal density become aesthetic and social markers. At the level of large scale temporal categories, Kramer's *The Time of Music* complements these accounts by offering an influential typology of musical temporalities and listening strategies, including linearity, nonlinearity, and multiple timescales, but it too leaves speed largely implicit within broader temporal categories.

Beyond music theory and time typologies, speed also remains largely implicit in research on musical expectation, auditory timing mechanisms, and flow. Much work in these areas concentrates either on structural parameters such as tempo, rhythmic patterning, and metric organization, or on experiential dimensions such as absorption, memory, and anticipation. On the structural side, London's account foregrounds tempo, beat hierarchies, and entrainment, while music psychologist David Huron's *Sweet Anticipation* (2006) models temporal expectation and prediction across multiple timescales, treating tempo primarily as a cue for expectation and emotional response. Cognitive neuroscientific work by Vani Rajendran, Sundeep Teki, and Jan W. H. Schnupp (2018) examines temporal processing in audition, including limits of temporal resolution, interval discrimination, and rhythm perception, focusing on timing mechanisms rather than on musical speed as an explicit category. At the experiential end, psychologist Andrea Chirico and colleagues (2015) review the literature on musical flow, surveying how states of absorption in performance, composition, and listening relate to temporal awareness. Together, these studies help specify cues and capacities that condition experienced speed, even when speed itself is not their organizing concept.

Speed is discussed indirectly in performance practice research and in laboratory based timing studies within music psychology, where tempo and timing are examined as resources and constraints in performance. Performance practice research has long explored tempo and timing as expressive resources. Performance scholar John Rink's edited volume *The Practice of Performance* (2015) brings together case studies of performance decision making, including discussions of tempo flexibility, rubato, and timing nuance, but its focus remains on interpretive practice within specific works rather than on speed as a cross cutting category that links compositional design, bodily effort, and listener perception. Within music psychology, music psychologist Bruno Repp's studies offer detailed experimental analyses of expressive timing and synchronisation. His article "A Constraint on the Expressive Timing of a Melodic Gesture" (1992) investigates how pianists shape timing within a specific phrase and how listeners evaluate such patterns. His later review "Sensorimotor Synchronization: A Review of the Tapping Literature" (2005) synthesizes empirical work on finger tapping to metronomes, probing accuracy, variability, and adaptation across tempi. These studies address tempo and timing with great precision, but they tend to treat tempo as an experimental variable rather than developing speed as a broader compositional, performative, and perceptual category. At the same time, they raise questions about how tempo and timing interact with affect and bodily load, which the next strand of research addresses more directly.

Scientific studies underscore the complexity of speed by examining timing accuracy and rhythmic synchronization across different tempi. Research on sensorimotor synchronization asks how accurately and flexibly performers can coordinate movements with external rhythms, and it reveals nonlinearities and tempo-dependent constraints that complicate any simple notion of "fast" or "slow." Repp's reviews on tapping and synchronization survey this literature, including findings on rate limits, error correction, and interpersonal coordination in ensemble contexts (Repp, 2005; Repp & Su, 2013).

A related strand links tempo to physiology and affect. Clinical researcher Ángel Fernández-Sotos and colleagues show how tempo and rhythmic units modulate listeners' emotional regulation, demonstrating that different combinations can be used to shift mood and arousal (Fernández-Sotos et al., 2016). Physiology researcher Archana E. Thakare and co-authors find that faster musical tempi can enhance physical exercises and influence heart rates in young adults, indicating that perceived speed interacts with motor effort and physiological load (Thakare et al., 2017). Researcher Yanhui Liu and colleagues demonstrate that tempo systematically shapes the emotional experiences of both musicians and non-musicians, with faster tempi associated with higher arousal and distinct affective profiles (Liu et al., 2018). Taken together, these findings support two points at once: tempo reliably correlates with physiological and affective responses, yet the lived experience of musical speed is not a one-to-one function of tempo alone. It is co-determined by rhythmic configuration, articulation, timbre, effort, and listening context, which is why the same nominal tempo can feel more or less fast, light, tense, or demanding.

London develops this line of thought in "What Is Musical Tempo?" (2023), arguing that musical tempo is not equivalent to beats per minute and that it should not be treated as a simple synonym for speed. Instead, he describes tempo as a summary judgement, a perceptual distillation of multiple cues that include beat hierarchies, rhythmic density, articulation, timbre, dynamic profile, visual gesture, and an embodied resonance with human motor rhythms such as walking (London, 2023). This expanded use of tempo overlaps substantially with what I call musical speed. The difference is not the cue set but the analytic orientation. London is primarily concerned with how listeners arrive at an integrated judgement of faster or slower from many inputs. My framework uses the same constellation to describe how pace is constructed in practice, through compositional design, performative technique, and notational decisions, and how these layers remain partially independent in performance and analysis. For that reason, I use tempo to refer to the inferred beat rate and metrical level that underpin entrainment and coordination, and I use musical speed to name the wider field of interacting layers through which pace is composed, enacted, and perceived.

Many of these cues coincide with the parameters that I foreground in this dissertation. The overlap is not accidental, since both London's account and my own treat musical time as something that emerges from the interaction of sounding events, bodily engagement, and culturally shaped habits of listening. The crucial difference lies in how the cues are framed. For London, they feed into a listener-oriented judgement that assigns a tempo to a piece or passage. In my account, the same cues belong to an ensemble of interacting layers through which speed is composed, enacted, and perceived, with tempo forming only one layer among others. Speed, as I will use and develop the term here, includes compositional design, performative techniques, and notational practice, as well as event density, layered temporality across parts and parameters, coordination, embodied effort and attention, and the cultural situatedness of listening and notation. Coming from practice-based research, it also addresses how speed is actively implemented in composing, improvising, and performing. Speed is therefore both perceptual and operational: it is a compositional strategy, a performative challenge, and a historically variable construct.

Building on these insights, this dissertation introduces a practice-based, artistic framework of musical speed that connects compositional design to performed enactment and to a listener's sense of pace. Drawing on Chapter 2 concepts such as perceptual thresholds, density, smooth and striated time, rhythmic embodiment, notational strategies, and situated musical knowledge, the framework treats tempo as one cue within a larger constellation that produces experienced speed. In the next chapter and the examples that follow, I use this framework to analyze specific passages from my own works and from selected works by other composers, showing how changes in density, temporal layering, notation, and coordination create layered speeds that are heard and felt in performance.

Artistic Research

To work towards a grounded answer to the question *What is speed in music, and how can I explore it creatively and practically within my artistic practice?* I carried out artistic research, an approach that foregrounds situated and embodied knowledge and treats musical practice as a site of inquiry. This orientation is important for a study of speed because what counts as fast, slow, stable, or unstable often emerges in doing: in bodily effort, coordination with others, rehearsal decisions, and the feedback loop between notation and performance.

Music theorist and philosopher Henk Borgdorff highlights the value of practitioner knowledge that is specific to artistic situations as follows:

> In the history of epistemology, the distinction is made between knowing *that* something is the case – theoretical knowledge, propositional knowledge, explicit knowledge, focal knowledge – and knowing *how* to do something, to make something – practical knowledge, embodied knowledge, implicit knowledge, tacit knowledge. (Borgdorff, 2012, p. 121, italics mine)

While this dissertation draws on both forms, it takes "knowing how" as its primary vantage point, using practical, embodied, and tacit forms of knowledge to ground and orient its theoretical claims about speed in music.

By explicitly presenting myself as both composer and performer within this research, I adopt a practice-based methodology anchored in concrete musical materials such as scores, recordings, instruments, and performance situations, and in specific procedures of making, rehearsing, and documenting. I analyze selected compositions through close work with scores, rehearsal and performance recordings, and reflective documentation of compositional decisions and performance experiments. This approach allows me to track how adjustments in tempo, density, articulation, gesture, and coordination change what performers can do and what listeners hear as pace.

Situated in an interdisciplinary space, this dissertation places these practice-based findings in dialogue with musicology, music theory, philosophy, and performance studies. The aim is not to claim a total account of musical time, but to develop a focused vocabulary and set of analytic tools for speed that can be applied across different musical repertoires and situations, for example across notated composition and improvisation, solo and ensemble performance, and studio and concert settings. Ultimately, by foregrounding speed as its central subject, this research offers a practice-based contribution to the study of musical temporality, with concrete ways to relate compositional technique, performed enactment, and experienced pace.

1.5 Outline

The two parts of my research question are addressed sequentially. Chapter 2 examines the first part, *What is speed in music?* Chapters 3, 4 and 5 address the second part, *How can I utilize speed creatively and practically within my artistic practice?*

In Chapter 2, I develop a working definition of speed in music as the rate of perceptual events in time, operating across multiple concurrent timescales and co-constructed by music, performer, environment, and listener. I build this account through five interlocking strands: thresholds of speed (exploring how temporal compression and expansion transform musical identity, from rhythm into pitch and texture), temporal resolution (biological limits of perception across species and their implications for human musical hearing), density and motion (showing how event density, gesture, and embodiment jointly shape perceived speed), smooth and striated time (elaborating and extending the work of Pierre Boulez, Gilles Deleuze/Félix Guattari, Gerard Grisey, and Brian Hulse, to propose a continuum rather than a binary), and finally the LEMI model proposed by Michelle Phillips and situated knowledge according to Donna Haraway, which allowed me to frame speed as an emergent, relational phenomenon. Throughout, I treat my own compositions and experiments as methodological tools, using them to probe perceptual thresholds, micro–meso–macro couplings and the interaction between notated grids, improvisatory agency, and performance context. Together, these perspectives prepare the conceptual ground for the more focused case studies in the later chapters.

In Chapter 3, I turn to tuplets as a central mechanism for shaping musical speed within subdivided time, and propose an expanded definition in which tuplets include both so-called irregular subdivisions and the metric subdivisions implied by the time signature. I trace their historical and conceptual origins, then develop a taxonomy of tuplet identities based on parity (even or odd), harmonicity, grouping strategies, and the rhythms articulated inside a subdivision grid, showing how each configuration produces a distinct felt character rather than a mere change in note count. Building on this, I introduce ratio tuplets, distinguish between "striation" tuplets (local grids) and "frame" tuplets (proportional tempo layers), and outline practical tools for performers such as stratification, frame reductions, and a system for quantifying speed changes between tuplets in percentages that can be read as tempo maps. In this chapter I also examine nested tuplets and complex polyrhythmic textures, arguing that such writing destabilizes the traditional 2:1 durational hierarchy and greatly expands the palette of temporal nuance available to composers and performers. Finally, by bringing the LEMI model and Haraway's notion of situated knowledge to bear on the performer–listener divide, I argue that tuplets are not abstract ratios but situated affordances whose identity and difficulty are co-constituted by bodies, instruments, notations, and environments. This lays the groundwork for later chapters, where the tools for regulating speed are connected to broader questions of polytempo, improvisation, and creative agency.

In Chapter 4, I extend the investigation of musical speed into polytempo, treating it as a site for examining how multiple concurrent temporalities are constructed and negotiated in performance. I begin by theorizing the rhythmic grid as a hierarchical structure of tuplets, beats, and bars, and systematically permute three basic parameters - pulse, tuplet and meter - into twelve possible configurations, of which six constitute genuine polytempo; this typology allows me to situate historical examples (Charles Ives, Carl Nielsen, Elliot Carter, Györy Ligeti, Conlon Nancarrow, and others) and to distinguish static from dynamic polytemporality. I then turn to my own works *Building Music*, *For Bob*, and *Sydney Polypulse* as compositional laboratories, in which I explore how choices of tempo ranges and ratios, tessitura–tempo mappings and tuplet based "speed extensions" shape the perceived motion and character of the resulting textures. A substantial part of the chapter addresses the performative and cognitive challenges of resisting entrainment in ensemble contexts: I analyze how different sensory modalities for metronome cues (visual, auditory, haptic) affect accuracy, I argue for the particular efficacy of haptic metronomes, and I develop the notion of the "inner robot" as a disciplined, embodied strategy for maintaining independent pulses while listening and responding musically. Through rehearsal-based reflection on *Sydney Polypulse*, I show how microtiming variability, phase duration, subdivision strategies, and attentional focus interact to produce or undermine the desired phasing effects, and argue that the artistic value of polytempo lies in the tension between mechanical regularity and human expressivity. Overall, the chapter presents polytempo music as both a compositional technique and a performance practice that brings metric, gestural, bodily, and technological kinds of speed into productive friction, reinforcing the claim that musical speed is a relational, situated phenomenon rather than a single scalar parameter.

Chapter 5 shifts attention from the sounding work to the act of making, and proposes a "speed of creation" model that treats improvisation and composition as points on a continuum of decision making rather than opposed categories. I map creative practices along two axes, creation speed and opportunity for deliberate choice, and refine this map with four parameters that recur throughout the chapter: temporal mode (real time or deferred time), workflow linearity, revision affordance, and the network of human and nonhuman actants that co-shape musical decisions. This framework is grounded in a detailed case study of my solo flute piece *Torrent*, which began as a maximal speed improvisation and was later fixed through transcription. Through this lens I analyze free improvisation as a methodological stance, the role of tactile interaction with the flute, chunking and real-time decision making at the limits of feedback and attention, and a layered experience of flow in which embodied automatisms and conscious monitoring remain in constant negotiation. The final sections turn to notation and re-performance, showing how an intentionally simplified rhythmic notation for *Torrent* both preserves the temporal fluidity of the improvisation and opens a specific interpretive space. I conclude by arguing that deadlines and time pressure in both real-time improvisation and deferred composition are powerful mechanisms for producing conviction, and that speed of creation is a central condition under which musical ideas become coherent, transmissible works.

Finally, the conclusion draws these strands together to articulate a synthetic account of speed as a relational, situated dimension of musical time that links technical parameters to lived temporal experience. There I show how the empirical and analytical investigations of thresholds, density, tuplets, and polytempo, together with the practice-based work on fast improvisation and speed of creation, converge with the philosophical frameworks of smooth and striated time, ecological and embodied listening, and situated knowledge into a single conceptual image: speed as an emergent property of relationships among events, bodies, media, and contexts rather than a simple numerical tempo. This synthesis reframes speed as both form bearing and meaning bearing, presents compositional tools and performance strategies as experiments in temporal physics, and reflects on the affordances and limits of an artistic research methodology rooted in my own practice. It also sketches implications for composers, performers, teachers, scholars, and technologists, proposing that treating speed as a central rather than a secondary musical parameter opens new possibilities for structuring works, designing pedagogies, developing technologies (such as haptic metronomes), and connecting artistic practice to cognitive science and philosophy.

Chapter 2: What is Speed in Music?

In this dissertation, I use the following working definition: *speed in music is the rate of perceptual events in time - functioning across multiple, independent yet concurrent timescales - co-constructed by the music, performer, environment, and listener.*

This chapter builds a definition of speed in music by investigating it from multiple, intersecting perspectives: scientific, philosophical, perceptual, and compositional. Rather than advancing a single theoretical argument, I present a constellation of approaches that reflect the multidimensionality of musical speed. Structured into five sections, the chapter addresses: the range of perceivable speed, human temporal resolution, the relationship between density and motion, the interplay of smooth and striated time, and the interaction between listener, environment, and musical stimulus, informed by situated knowledge. These sections can be read independently or in sequence, and together form a nonlinear cartography of the topic. My own compositions function throughout not merely as illustrations but as methodological tools: the music becomes both subject and mode of inquiry. The chapter seeks to excavate speed's complexities, highlighting the transformations of its identity that occur at perceptual limits, the entanglements between pulse and density, and the ways in which speed emerges through the joint shaping of contextual factors.

2.1 Thresholds of Speed

Example 2.1. "Four Criteria of Electronic Music," Oxford Union lecture, video excerpt. (Stockhausen, 1972/1989)

In a lecture delivered at the Oxford Union in 1972, composer Karlheinz Stockhausen speculated on the effects of extreme temporal compression and expansion in music, likening the idea to manually accelerating an LP by spinning it faster with a finger. Building on his proposal to compress a Beethoven symphony into the duration of one second without altering its pitch, I created 24 additional versions of Beethoven's *Symphony No. 9 in D minor, Op. 125* at various speeds.[4] These digital sound files span an extensive temporal range, revealing both the musical possibilities and the perceptual boundaries inherent to our auditory system. These two topics - the compositional and expressive potential of extreme temporal manipulation, and the perceptual thresholds that define how we experience such transformations - serve as central themes in this section. The first version is a fragment of the entire symphony stretched to 24 hours, producing slow-motion renderings of orchestral gestures. At the other extreme, the full symphony is looped at such a high frequency that the resulting sound exceeds the upper limit of human hearing.

With each successive iteration, as speed increases, the identity of the music is transformed. In some cases, the change simply results in a faster rendering of the same recognizable material; the musical content remains legible. In others, the transformation is more radical: singable melodies dissolve into texture, and entire movements are compressed into brief moments. Across the series, the perceptual window shifts - from a single note to a motive, to a phrase, to a block of phrases, to a section, to a movement, until finally the entire symphony is apprehended in a flash. Composer and computer programmer Curtis Roads illustrates this kind of temporal scaling in his figure "Time Scales of Music" from *Microsound* (2001), which maps the time domain across a continuum segmented into periods, time-delay effects, frequencies, and zones of perception and action. His chart provides a conceptual framework to situate, across time scales from the macroscopic to the infinitesimal, the Beethoven transformations within a broader spectrum of temporal experience, showing how changes of scale alter not only what we hear but how we can act within those temporal regimes.

[4] These versions were created with the technical assistance of Bas Bouma.

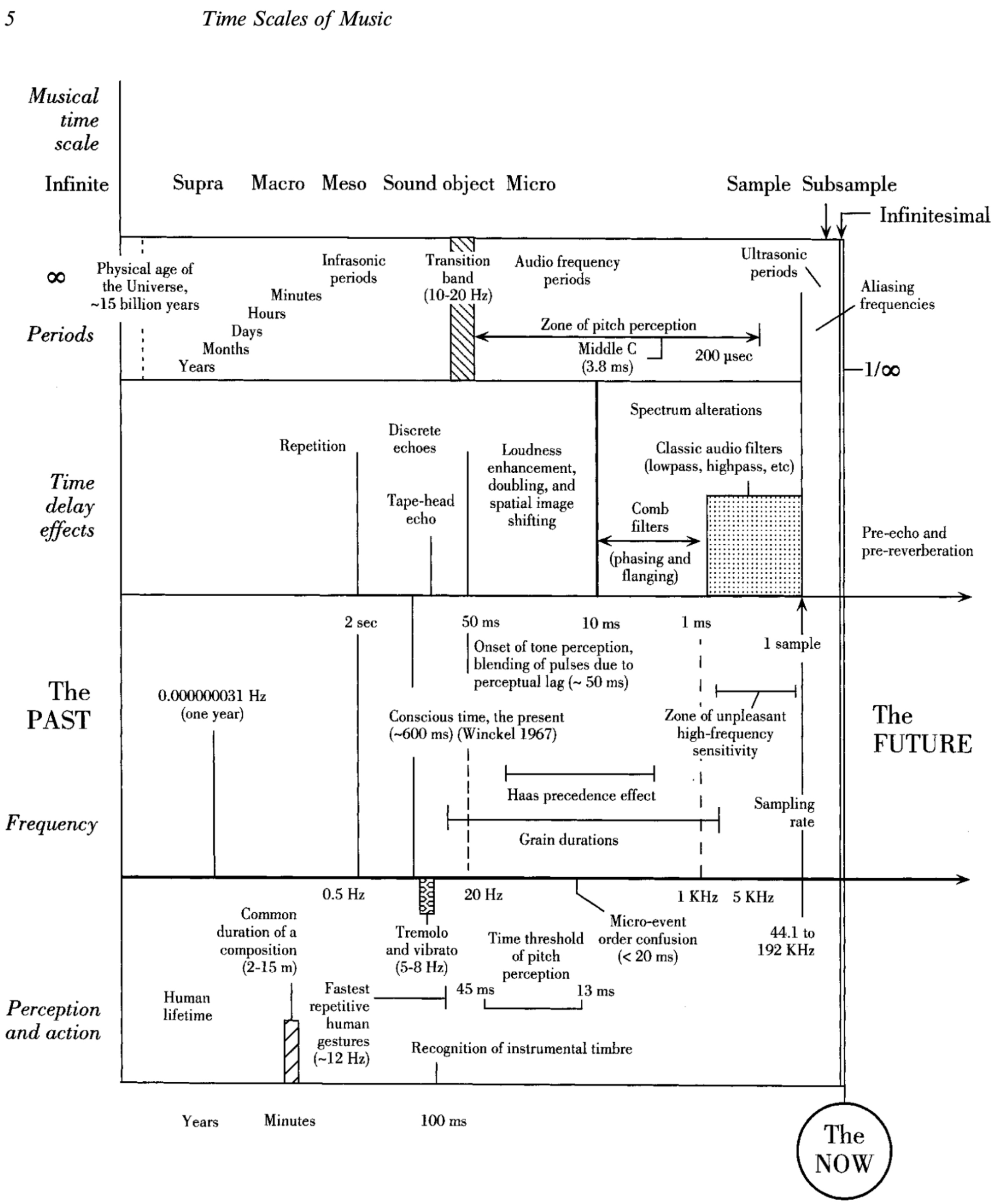


Figure 2.1. Time Scales of Music.
Reprinted from *Microsound* (Roads, 2001, p. 5).

A visual mirroring of this effect is seen in the film *Powers of Ten* (Eames & Eames, 1977), in which the camera zooms out to successively larger scales of space. At certain stages, the view simply expands to include broader spatial dimensions; at others, the visual field undergoes a fundamental shift in character.

Similarly, the Beethoven examples reveal how changes in speed can reconfigure musical identity in sound. Stockhausen's theoretical work systematized this relationship, postulating a unified time domain where rhythmic durations and musical pitches are perceived merely as contractions or expansions along a single continuous speed scale (Stockhausen, 1959).

A critical perceptual threshold is crossed when the symphony is compressed to 0.05 seconds and repeated. At this point, the human auditory system can no longer resolve individual events; instead, the repetitions are perceived as a single pitch. This corresponds to what is known in psychoacoustics as the "auditory flutter fusion threshold," typically around 20 Hz, below which pulses are perceived discretely and above which they are fused into one pitch (Besser, Duncan, & Quilliam, 1966, p. 751; Moore, 2012, pp. 60-61). The discrete waveforms blur together, producing a sustained vibration that is perceived as a single, continuous tone. As the looped duration continues to halve, this composite sound gradually simplifies - its overtone complexity decreases - producing a purer pitch. With each doubling of the playback speed, the pitch ascends by octave increments, until it eventually moves beyond the range of human hearing.

These transformations are not continuous but punctuated by perceptual thresholds - points at which the auditory system re-categorizes input into fundamentally different perceptual objects. Such thresholds reveal the multi-layered architecture of temporal perception, where rhythm becomes pitch, gesture becomes texture, and structure becomes instantaneous gestalt.

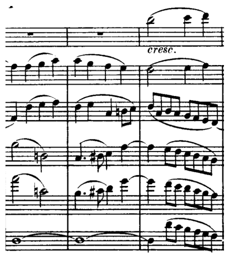
Before presenting the following excerpts, it is important to clarify how I am using several musical terms related to temporal scale. By "motif" I mean a concise unit, often between one and five notes, that conveys a recognizable identity. By "phrase" I mean a larger unit of musical thought, comparable to a phrase in language, which carries a sense of articulation and completion. By "gesture" I mean a more fluid musical event, shaped by dynamics, contour, and texture, which may or may not correspond to traditional motivic or phrasal boundaries. Later in this chapter I also situate these categories within the framework of micro, meso, and macro timescales (Godøy & Leman, 2010, p. 121; Godøy, 2018). These two systems are not identical: motif, phrase, and gesture describe qualitative kinds of musical units, while micro, meso, and macro describe durational scales of organization. The overlap between them will be made explicit below.

Here follow the 25 Beethoven speed transformations.

1/24 speed: with the full symphony stretched to an entire day, the sound of the orchestra is nearly motionless, suspended in time. The unfolding of a single bar of music yields a glacial blossoming of the sound. This durational concept was first realized by Norwegian artist Leif Inge in the sound installation *9 Beet Stretch* (2002), in which the complete Ninth Symphony was digitally time-stretched to 24 hours without pitch alteration.

Example 2.2. *Symphony No. 9 in D minor, Op. 125*, score excerpt. 1/24 speed, audio excerpt.

1/8 speed: melodic fragments begin to emerge, and other layers drift in slow motion.



Example 2.3. Score excerpt. 1/8 speed, audio excerpt.

1/2 speed: the theme becomes clearly recognizable, though still far below the intended tempo.

Example 2.4. Score excerpt. 1/2 speed, audio excerpt.

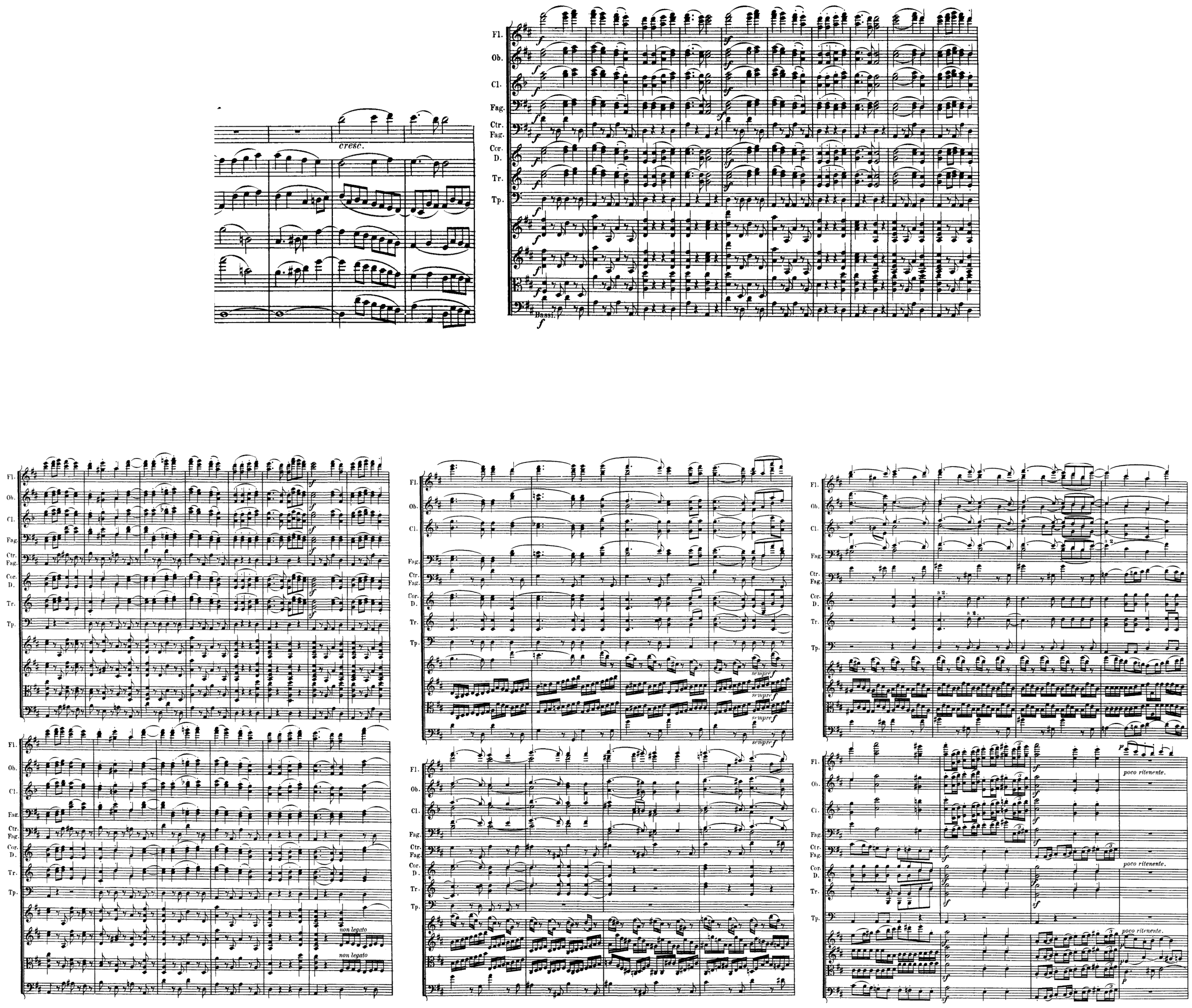
Original speed: this is the original tempo of the symphony, although to me it sounds surprisingly fast when preceded by the slowed-down versions.

Example 2.5. Score excerpt. 1x, audio excerpt.

Two times faster: a brisker rendering of the original - perhaps slightly comical. The musical information remains intelligible, but digital artifacts become noticeable.

Example 2.6. Score excerpt. [2x faster](#), audio example.

Four times faster: the theme now unfolds at the pace of motivic cells.



Example 2.7. Score excerpt. [4x faster](), audio excerpt.

Eight times faster: entire phrases are reduced to motivic length. While the theme is barely discernible, structural features such as the occurrence of contrasting sections and harmonic modulations remain audible.

Example 2.8. 8x faster, audio excerpt.

Sixteen times faster: at this speed, melodic material is rendered as a blur. The harmonic modulations occur more quickly, revealing both a transformation and a temporal compression.

Example 2.9. 16x faster, audio excerpt.

Entire symphony in one minute (approximately 70x faster): all melodic and harmonic content has become inaudible. Instead, macro-level dynamics are foregrounded.

Example 2.10. Full symphony, in 60 seconds, audio excerpt.

In five seconds: only large-scale gestures remain perceptible, such as the choral entrance in the final movement.

Example 2.11. Full symphony, in 5 seconds, audio excerpt.

In one second: Stockhausen's vision is realized here. Despite the extreme compression, some elements from the five-second version are still faintly recognizable.

Example 2.12. Full symphony, in 1 second, audio excerpt.

1/10th of a second: although some vocal color is still distinguishable from the rest, the entire symphony has become mostly one sound.

Example 2.13. Full symphony, in 0.1 seconds, audio excerpt.

1/20th of a second: the symphony is reduced to a uniform sonic event - brief, dense, and uniform.

Example 2.14. Full symphony, in 0.05 seconds, audio excerpt.

Loop at 20x per second: when this short sound is looped at 20 Hz, it enters the threshold of pitch perception. The sound retains complexity, as some of the original recording's information remains embedded within it.[5]

Example 2.15. Loop, 20 Hz, audio excerpt.

Loop at 40x per second: the resulting tone is clearly audible and low, still textured and machine-like.

Example 2.16. Loop, 40 Hz, audio excerpt.

Loop at 80x per second: as the frequency doubles, the pitch ascends by one octave.
The timbral density begins to simplify, moving toward a purer tone

Example 2.17. Loop, 80 Hz, audio excerpt.

Example 2.18. Loop, 160 Hz, audio excerpt.

Example 2.19. Loop, 320 Hz, audio excerpt.

Example 2.20. Loop, 640 Hz, audio excerpt.

Example 2.21. Loop, 1280 Hz, audio excerpt.

Example 2.22. Loop, 2560 Hz, audio excerpt.

Example 2.23. Loop, 5120 Hz, audio excerpt.

These successive doublings continue the process of simplification, with each octave shift rendering the tone increasingly sine-like, as more of its overtones exceed the frequency range of human hearing.

Example 2.24. Loop, 10240 Hz, audio excerpt.

This lies near the upper perceptual limit for many middle-aged adults. The tone may already sound faint or piercing, depending on playback equipment and listener sensitivity.

[5] If Beethoven's entire 70-minute Ninth Symphony (44.1 kHz) is collapsed into a single 20 Hz loop (a 50 ms segment that repeats), that loop contains about 2,205 samples, which is 1/84,000 of the original data, i.e. roughly 0.0012% of the original recording's information.

Example 2.25. Loop, 15360 Hz, audio excerpt.

Approaching the hearing threshold for younger listeners. Although not an exact octave higher, it sits roughly halfway to the upper limit of human hearing, making it useful for self-testing one's auditory range.

Example 2.26. Loop, 20480 Hz, audio excerpt.

At this frequency, the looping of Beethoven's 9th has crossed the threshold of human audibility. The final transformation illustrates how musical information, when accelerated beyond perceptual resolution, becomes abstracted into pitch - or disappears entirely.

Throughout these examples, musical materials undergo a transformation as they are presented at different speeds, underscoring the powerful role speed plays in shaping musical identity. Minor alterations in speed may lead to subtle shifts in character, but beyond certain thresholds more substantial changes provoke fundamental reconfigurations of the material. These perceptual shifts arise when the relationship between the sound and the listener's cognitive and sensory systems is disrupted or recalibrated (Moore, 2012, pp. 57-66). This relationship is shaped not only by the physiological limits of perception but also by contextual factors outlined in the LEMI model as proposed by music psychologist Michelle Phillips in *Music and Time* (Phillips, 2023, pp. 11-28) and philosopher Donna Haraway's theory of situated knowledge (Haraway, 1988), which emphasize the influence of a listener's physiological and psychological condition, their environment, and their attentional orientation. The traversal through a continuum of speeds demonstrates that there is no absolute "maximum speed" in music; rather, there are transition points - thresholds at which perception reorganizes itself and musical identity is renegotiated. These thresholds offer fertile ground for further inquiry into how musical material is perceived differently or structurally reinterpreted as speed surpasses perceptual limits, revealing not only altered musical identities but also new forms of listening, interpretation, and compositional possibilities.

Transformation

It is important to note that these 24 versions were created digitally, using software that compresses or expands the audio by algorithmically selecting which information to retain and which to discard (Collins, 2010, pp. 53-54). As a result, the transformations in sound are not purely the result of speed change; they also reflect the influence of *digital artifacts* introduced by the processing. These artifacts - glitches, smearing, or unnatural timbral changes - can shape the way we perceive the music at different speeds (Roads, 2001, pp. 198, 343). This raises a speculative but important question: as digital audio technology continues to advance and such digital artifacts are increasingly minimized or eliminated, will our perception of musical identity shift in response? In other words, as the sonic image - understood here as the organized perceptual gestalt arising from auditory input[6] - becomes more acoustically transparent and less distorted by processing, will the thresholds at which we perceive speed-induced changes in musical character also shift? Improved clarity might reveal new continuities or distinctions we cannot perceive under current technological conditions.

This question has a precedent. In the analogue era, Stockhausen formulated a unified view of musical time through systematic tape-speed transformations in *Kontakte* (Stockhausen, 1958–60/1960; see also Stockhausen, 1989, pp. 95–105; Dack, 2009, pp. 6–8).. There, accelerated pulses fuse into tones and

[6] In this context, the notion of a perceptual gestalt refers to the way the auditory system organizes and integrates discrete sonic elements - pitch, rhythm, and timbre - into coherent wholes. Rather than perceiving isolated stimuli, listeners experience unified sonic forms shaped by principles of proximity, similarity, and continuity. This gestalt perception is essential to musical understanding, especially when rapid temporal transformations challenge the brain's capacity to maintain coherence across changing sensory data (Tenney, 2015, pp. 27 - 38).

decelerated tones fracture into pulses, making audible how identity depends on temporal resolution. The later advent of digital processing extended these techniques by decoupling pitch from duration and exposing microtemporal structure with greater clarity (Roads, 2001, pp. 179-193; Roads, 2015, p. 113). The Beethoven examples above are a direct result of these digital capabilities. As the technical substrate has evolved, so too have the thresholds at which listeners construe a sound as the same or as something new (Smalley, 2001, pp. 107–126).

Still, the examples remain effective as demonstrations of how musical identity can shift across a spectrum of temporal resolutions. Since speed manipulations in digital processing operate near the physiological boundaries of human perception, a more relevant issue, from an artistic point of view, is not whether finer resolution will wholly transform experience, but how we conceive of the sound object under such conditions. Composer Michel Chion's formulation regarding fidelity in cinema sound is instructive: "The film spectator recognizes sounds to be truthful, effective, and fitting not so much if they reproduce what would be heard in the same situation in reality, but if they render - convey, express - the feelings associated with the situation" (Chion, 1994, p. 108). By analogy, judgments of fidelity in temporally transformed music may depend less on acoustic verisimilitude than on the expressive adequacy of the transformed sound.

Roads makes a complementary point: "The choice of whether to alter a sound beyond recognition depends on its function […] there are no universally 'good' filters or 'bad' reverberators in the absolute sense, just as there are no inherently 'good' or 'bad' sounds. Everything depends on the context in which the transformation is applied" (Roads, 2015, p. 118). In the Beethoven case, the function is to test the perception of speed, yet emergent factors play particularly interesting and artistic roles. Since the samples originate from acoustic instruments, they generate a kind of auditory fiction when subjected to extreme speed transformations (Collins, 2010, p. 7). The altered recordings evoke performances that no orchestra could physically realize, as the required tempi would surpass the physiological limits of human performers. However, rather than treating such impossibilities or their resulting artifacts as deficiencies, they may be approached as creative opportunities.

In *Tools* (2003), I explore this concept through compositional processes that accelerate and reshape recurring material. As the titles of movements 5, 6, and 7 grow progressively longer, the music itself accelerates - a structural device intended to create surprise as the listener encounters familiar material reappearing at increasingly rapid speeds, drawing the listener into a shifting temporal landscape.

Example 2.27. *Tools*, "Pneumatic Screed" movements, score and audio excerpt.

In the final section of the movement "Telescopic Ladder" (2003), a similar acceleration process unfolds across multiple levels within a four-voice temporal canon. After each iteration, the second phrase introduces quintuplets that serve as the mechanism for a metric modulation, ratcheting the music into a faster tempo. With each cycle, the material is also transposed upward, producing a pitch-rising effect reminiscent of the acceleration heard when an LP is manually sped up. Eventually, the acceleration reaches a point approaching performable limits, at which the score instructs the musicians to improvise, emulating both the transpositional and temporal intensification. The music quickly morphs into chaotic textures, evocative of a shift from the familiar domain of performable notes into a microcosmic world of racing particles and atomic motion.

Example 2.28. *Tools,* "Telescopic Ladder" final section, score and audio excerpt.

This erosion of accuracy at extreme speeds should not be seen merely as failure but as the genesis of new artistic material. When musicians can no longer maintain precise control, what emerges are novel sonorities, rhythms, and textures - artifacts of collapse that can be deliberately harnessed as compositional resources. At the extremes of speed, musical material becomes a site where expression is no longer dictated by precision, but instead arises from energy, density, and transformation. In this way, speed becomes not only a parameter of change but also a catalyst for invention.

2.2 Temporal Resolution

Time perception depends on how rapidly an animal's nervous system processes sensory information.
(Reas, 2014, p. 11)

This section explores how temporal resolution functions across various species, with special attention to human musical perception and cognition. Examining the speed at which different organisms process sensory input reveals the biological foundations of temporal experience, and highlights how these mechanisms shape the ways humans perceive, respond to, and create music.[7]

The speed at which attention operates in animals, including humans, is fundamentally determined by how quickly sensory information is detected and processed by their neurological and cognitive systems. These perceptual speeds, which influence human musical perception and experience, originally evolved as survival mechanisms; rapid sensory processing can mean the difference between life and death in the wild. However, maintaining such high-speed perception demands substantial energy. Animals protected by robust physical defenses, like shells, typically exhibit slower perceptual speeds, having invested energy in the construction of their shells rather than maintaining rapid reaction times (Land & Nilsson, 2012, pp. 18, 69).

Physiological and environmental factors have led to significant variations in perceptual processing speeds across different species, commonly quantified using the *critical flicker fusion rate* (CFFR). In measuring CFFR, researchers expose animals to a flashing light and observe neuronal activity corresponding to each flash. As the frequency of flashing increases, animals eventually reach a perceptual threshold at which they no longer discern individual flashes; instead, they perceive the light as a continuous illumination (Inger, Bennie, Davies, & Gaston, 2014, p. 1).

To illustrate the significant differences in maximum processing visual speeds across species, the following list presents average CFFR values:

- Human: 60 Hz
- Housefly: 250 Hz
- Pigeon: 100 Hz
- Dog: 80 Hz
- Cat: 55 Hz
- Rat: 39 Hz
- Leatherback Turtle: 15 Hz

As can be seen, flies can process visual information more than four times faster than humans. The result is that it is usually difficult for humans to swat a fly, because the swatting hand approaches very slowly for the fly. Likewise, we process visual events four times faster than a turtle. If a turtle tried to walk over our foot we would have no problem getting out of the way.

An analogous perceptual phenomenon exists in human auditory perception and is referred to as the *auditory flutter fusion threshold*, as mentioned in Thresholds of Speed. At low frequencies, listeners distinctly perceive individual repetitions of a brief sound. However, as the frequency increases, these discrete

[7] There is a growing body of research on how animals perceive, and in some cases produce, musical sounds. While this dissertation focuses on human musical perception, notable studies include Patel (2008), Fitch (2006), and Snowdon and Teie (2010).

auditory events begin to blur, and at approximately 20 Hz - the flutter fusion threshold for most humans - they are perceived as a continuous tone (Besser, Duncan, & Quilliam, 1966, p. 751; Moore, 2012, pp. 60-61). This threshold marks the point at which temporal resolution gives way to pitch perception: repeated auditory events are no longer distinguishable in time but are integrated into a steady auditory image. As demonstrated in the Beethoven speed transformations, musical pitches created by repeated sounds require a rate above this perceptual boundary.

It should be emphasized that this threshold applies specifically to repeated sounds; humans remain capable of detecting transient or non-repetitive auditory events occurring at much higher rates, such as rapid melodic figures, subtle articulations or shifts in timbre and spatial positioning, particularly when aided by stereo hearing (Blauert, 1997, p. 27; Lieberman, 1986, p. 139). To explore and experience the speed of *changing* notes which don't transition to a sustained pitch in our perception, below is a series of recordings of notes at increasingly faster speeds. The rates are given in three different units: milliseconds, beats per minute and in Hertz. The intention here is to demonstrate for the reader to experience for themselves at which speed the individual notes cease to become unique events, providing one approach to quantification of our experience of speed. This series of examples is a "cousin" of the Beethoven examples, but it is concerned with the experience of single-note speeds instead of the transformation of larger musical structures such as motives, phrases, sections, and movements under temporal compression and expansion.

Example 2.29. Temporal Resolution audio examples

- 150 ms - 400 bpm - 6,667 Hz[8]
- 100 ms - 600 bpm - 10,000 Hz
- 90 ms - 668 bpm - 11,111 Hz
- 80 ms - 752 bpm - 12,500 Hz
- 70 ms - 856 bpm - 14,286 Hz
- 60 ms - 1,000 bpm - 16,667 Hz
- 50 ms - 1,200 bpm - 20,000 Hz
- 40 ms - 1,500 bpm - 25,000 Hz
- 30 ms - 2,000 bpm - 33,333 Hz
- 20 ms - 3,000 bpm - 50,000 Hz
- 10 ms - 6,000 bpm - 100,000 Hz
- 5 ms - 12,000 bpm - 200,000 Hz

For a musical example close to the fastest speeds in these examples, see Conlon Nancarrow's *Study No. 21 (Canon X)* (1960). Towards the end the speed of notes reaches 110 notes per second, which is 9 ms per note.

Finally, speeds even faster than those explored here do play a role in the perception of sound, as excavated in detail in *Microsound* (Roads, 2001). Roads's distinction between sound objects and the worlds of shorter events (microsounds, samples, and subsamples) explores the limits of human conscious perception, not only biologically between the speeds of our cognitive and mechanical hearing systems, but also musically in terms of exploring the building blocks of sound and how they affect our hearing.

[8] For these examples a randomized serial sequence of notes without repetition or perceptible patterns was chosen.

In order to situate humans' mechanisms for perceiving pitch within a broader biological context, it is useful to compare auditory frequency ranges across species. Such comparisons also help illuminate the biological basis of temporal resolution, since the ability to detect rapid fluctuations in sound is closely tied to the frequency range an organism can perceive. Below are the ranges of audible frequencies for various animals:

	Hearing range in Hz
- Humans	20 – 20,000
- Bats	2000 – 110,000
- Bottlenose Dolphin	90 – 105,000
- Beluga Whale	1000 – 123,000
- Elephant	16 – 12,000
- Dog	67 – 45,000
- Cat	45 – 64,000
- Rat	200 – 76,000
- Chicken	125 – 2,000
- Horse	55 – 33,500

Bats, which rely on echolocation to hunt, possess extraordinarily fine temporal resolution. Each sonar call and its returning echo functions like a brief "stroboscopic snapshot" of the surroundings; successive echoes arrive so rapidly that the auditory system stitches them into a continuous spatial image. In the final moments of a hunt, a bat's vocal muscles can fire up to 200 times per second, producing a rapid terminal buzz that allows it to track tiny changes in the prey's position on the scale of milliseconds (Yong, 2022, pp. 342–343). By contrast, human auditory sensitivity is optimized for speech, particularly in the range around 250 to 8,000 Hz. This tuning supports nuanced phonetic and prosodic distinctions and also sharpens our perception of ecologically salient sounds such as rustling or alarm calls; within this band, temporal acuity for rhythmic and onset cues is especially high (Yong, 2022, p. 294; Kraus & Chandrasekaran, 2010, p. 601). These values should not be read as a single numerical ranking of "who hears fastest," since they arise from different measures and are tuned to distinct perceptual tasks. Rather, they indicate how each species has adapted its auditory system to particular ecological demands, and they provide a biological background for understanding the limits and possibilities of human temporal perception in music.

Modulation

Interestingly, some species demonstrate the ability to modulate their perceptual speed dynamically. Swordfish dwelling in cold, deep waters heat their eyes to raise flicker-fusion rates, thereby enhancing the tracking of rapid visual events (Fritsches et al., 2005, p. 55). Bats likewise scale echolocation to context: relatively sparse pulses suffice for general navigation, whereas during prey capture they accelerate into the terminal buzz, greatly increasing temporal resolution for intercepting fast-moving targets (Schnitzler & Kalko, 2001; Yong, 2022, pp. 342–343). This task-dependent scaling exemplifies a dynamic speed of attention that follows the rate of incoming information. Music, similarly, presents information at varying temporal speeds, thus dynamically influencing the listener's attentiveness. As the complexity or speed of musical input increases, human cognitive and perceptual systems may adjust their attentional allocation, either sharpening focus to match increased demands or losing detail if the information exceeds perceptual capacities (Large & Jones, 1999, p. 119).[9]

[9] The nature of this process is fundamentally governed by the Dynamic Attending Theory (DAT), where attending is conceptualized as the entrainment (synchronous interaction) between external driving rhythms in the music and internal driven neural oscillations (Jones, 2019, pp. 368, 479). Sharpening focus is achieved by dynamically adjusting and actively boosting the amplitude (energy) of the relevant internal oscillations (Jones, 2018, pp. 383, 480), enabling

While scientific testing often aims to simplify temporal resolution to single numerical values (e.g., quintuplet sixteenth notes at 80 beats per minute yielding 400 notes per minute), musical reality resists such simplification. Music simultaneously incorporates multiple temporal layers, explicitly and implicitly expressed not only through rhythmic parameters such as tempo, meter, tuplets, and rhythmic patterns, but also through the unfolding developments of melody, harmony, timbre, articulation, dynamics, and texture. These layers can occur between different instruments or even within a solo instrument, as when a performer plays or implies concurrent rhythmic or expressive streams across registers or articulations (Huron, 2006, p. 183; Clarke, 1999, p. 473). Each of these musical elements evolves concurrently at its own rate, creating intricate temporal interactions that defy simple numerical representation. Musical speed, therefore, manifests as a multi-dimensional, relational phenomenon, deeply embedded within biological constraints and general mechanisms of human perception and cognition. This multi-layered, concurrent, and relational complexity, which resists reduction to isolated variables, makes music very difficult to study using traditional scientific methods. However, through artistic research, music can offer powerful contributions to existing knowledge by providing experiential and practice-based insights into temporal perception.[10] More specifically, artistic research keeps intact the coupling of body, instrument, ensemble, and environment, and it works through iterative cycles of making, performing, and listening that surface tacit know-how and boundary phenomena. These practices function as performative probes that disclose thresholds, affordances, and breakdowns that are often hidden by variable isolation or decontextualized stimuli. The resulting artefacts and procedures covered in this dissertation, such as scores, recordings, techniques, and protocols are publicly inspectable and can be re-enacted by others, which enables intersubjective testing within practice. These strengths do not imply that experiential inquiry alone covers all of musical complexity; rather, they complement and at times correct experimental and computational approaches by situating claims within lived musical action.

The preceding examples of animal and human perceptual thresholds underscore how perceptual processing speeds fundamentally shape human experience of time. From the perspective of musical perception, the concepts of CFFR and auditory fusion - including the auditory flutter fusion threshold - provide a biological foundation for understanding how music engages human temporal resolution. Music acts as information structured temporally, sometimes explicitly interacting with the thresholds and limits of human perceptual faculties. This raises critical questions for musical practice and theory: Is the music comfortably aligned with human perceptual capacities, excessively slow, or so rapid as to blur perceptually? Furthermore, it prompts consideration of how composers and performers might deliberately work with temporal complexity to explore the boundaries and potentials of human perceptual engagement, enriching both the practice and the understanding of music.

My etude *The Speed of Time* (2014) effectively demonstrates the interaction between rhythm and meter as temporal layers in music. Designed to be performed at a strict tempo, each bar throughout the entire piece lasts precisely six seconds, as indicated by audible metronome clicks. Initially, the temporal resolution is very low, with only one note per bar. As the piece progresses, the number of notes per bar increases, introducing more complex tuplets and higher rhythmic density, thus significantly increasing the

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targeted anticipatory attendance (Jones, 2019, pp. 413, 273). Conversely, the system loses detail when increased rhythmic complexity, which is often tied to less stable attractor ratios (Jones, 2019, 398), consequently narrows the oscillation's entrainment region (Large & Jones, 1999, pp. 124, 127; Jones, 2019, pp. 247, 479). This results in a failure of synchronization when temporal input irregularities exceed these precise perceptual constraints (Large & Jones, 1999, p. 119; Jones, 2019, p. 247). For a further detailed application and formal framework of this process, see Jones, M. (2019), *Time Will Tell: A Theory of Dynamic Attending*.

[10] For example, in Chapter 4, musicians choose placements of haptic metronomes for a variety of reasons which are not explained by scientific research alone.

informational content. This gradual addition of events - from sparse to increasingly dense - is intended to stimulate a quicker attentional response in an engaged listener, altering their perceived temporal resolution.

Example 2.5. *The Speed of Time*, score and video example.

As a compositional experiment, *The Speed of Time* serves as a practical demonstration of many of the perceptual concepts outlined in this section. Unlike the musical examples in the section Thresholds of Speed, which explore the perceptual boundaries where repeated sounds become pitch or texture, or the exploration of creation at physical and cognitive limits in the Chapter 5, this piece operates well within the zone of human perceptual capacity. Its focus lies not in testing the limits of what can be perceived, but in examining how multiple temporal layers interact and influence the subjective experience of musical time. The use of the metronome as a fixed, external reference might echo the kind of measured regularity often favored in psychophysical and cognitive studies of rhythm and timing, but in this context it was not chosen to simulate scientific testing. Rather, it serves to illuminate the contrast between clock time and human time, highlighting how subjective temporal experiences can diverge from mechanical regularity. This also resonates with the distinction between striated and smooth time: striated time organizes musical events into regular, countable divisions, whereas smooth time unfolds as a more continuous, less segmented duration. As the etude morphs from long stretches of undefined silence into regular divisions, and as note articulations increase within the constant periodic metronome clicks, it reveals how temporal resolution can modulate our experience of time, engaging attention differently across varying musical layers.

In this way, *The Speed of Time* is first and foremost a musical work that, in this dissertation, informs theoretical inquiry, illustrating how musical practice can serve as a lens for investigating human temporal resolution. A deeper dive into the role of density in shaping musical time and experience is carried out in the section Density and Motion.

2.3 Density and Motion

> *Contrasts of temporal density have become a prominent feature of music, and […] it is the increased rate of change in temporal density that is most noticeable, rather than the absolute range of differences between the slowest and the fastest extremes.* (Tenney, 1961/2015, p. 24)

While the sections Thresholds of Speed and Temporal Resolution considered speed at "slowest and fastest extremes," this section considers the implications of density and motion of perceptible speed *within* those extremes. Tenney's remark points to a central concern of this section. What most affects our experience is not simply how dense a texture is, but how quickly that density changes, within the limits of human attention. In this section I treat density as one of the main ways in which speed is articulated in music: by increasing or decreasing the number of events per unit of time, by redistributing them across instruments and registers, and by changing how they are grouped. I draw on selected theoretical accounts and on close readings of musical passages where shifts in density alter the perceived motion and, at times, the very identity of the material.

Tenney describes temporal density as the number of musical events - such as note onsets, dynamic inflections, articulations, timbral changes, or other perceptual markers that indicate change or emphasis - occurring within a given span of time (Tenney, 1961/2015, p. 408). This quantity can be calculated numerically, offering a way to gauge how saturated a passage of music is with activity, and thus may serve as a proxy for musical speed in analytical or computational approaches.

Tempo, usually defined in terms of beats per minute, represents one specific type of density: the density of pulses, which may or may not be continuously present in the sounding music, and is sometimes only implied by the patterns that are heard. Because it provides a regular and measurable reference, tempo is often taken as the default indicator of musical speed. For example, the much-debated case of Beethoven's metronome markings, frequently judged excessively fast compared to most recorded performances (Mélon, 1984; Martens, 2010), shows how the same score can yield very different densities depending on the realized tempo. In discussions of speed, tempo functions as a shorthand parameter: it captures one dimension but overlooks the rich variety of factors that shape the perception of speed. Likewise, note onset offers a shorthand for density: the number of individual note beginnings within a span of time serving as a measure of event density. Iannis Xenakis' composition *Achorripsis* (1957) demonstrates this by dividing the piece into 28 time segments, each with a specified number of sound events determined probabilistically (Bökesoy, 2024). In this way, the composition treats the number of note onsets per segment as a structured parameter, directly embodying Tenney's concept of temporal density. Dynamic inflections (sudden changes in loudness) can also serve as perceptual events that increase temporal density. In *Klavierstück IV* (1952), for instance, Stockhausen layers two contrapuntal voices - one almost exclusively fortissimo, the other pianissimo - so that the perception of density arises not only from the number of notes but also from the friction of their extreme dynamic identities, creating a texture in which dynamic contrast itself becomes a primary structuring of density.

These are only a few of the parameters that together form temporal structures, whether quantized - such as meter, rhythm, and tuplets - or irregular, such as rubato and expressive timing.[11] Their interplay continuously reshapes the listener's sense of motion, modulating temporal expectation and the expressive flow of musical time. Composer Gérard Grisey similarly explored density but focused more explicitly on its perceptual and spectral dimensions. Grisey described density as fundamental to our perception of musical

[11] The implications of this layered conception of time, encompassing both regular and irregular structures, are taken up further in the section on Smooth and Striated Time.

time, shaping listener experience through the acceleration or deceleration of sonic events, replacing traditional pulse with evolving sound masses that articulate form as shifting energies (Grisey, 1987, pp. 248-249). Grisey stated that "[…] the tempi in my music seldom have a structural value. More often, they serve to compress or expand a musical sequence, and it is therefore the total duration of this sequence which is structurally important, and not the unit of measurement" (Grisey, 1987, p. 242) Tempo, then, is just one layer of speed: not always the most perceptually salient, and only one aspect of temporal density.

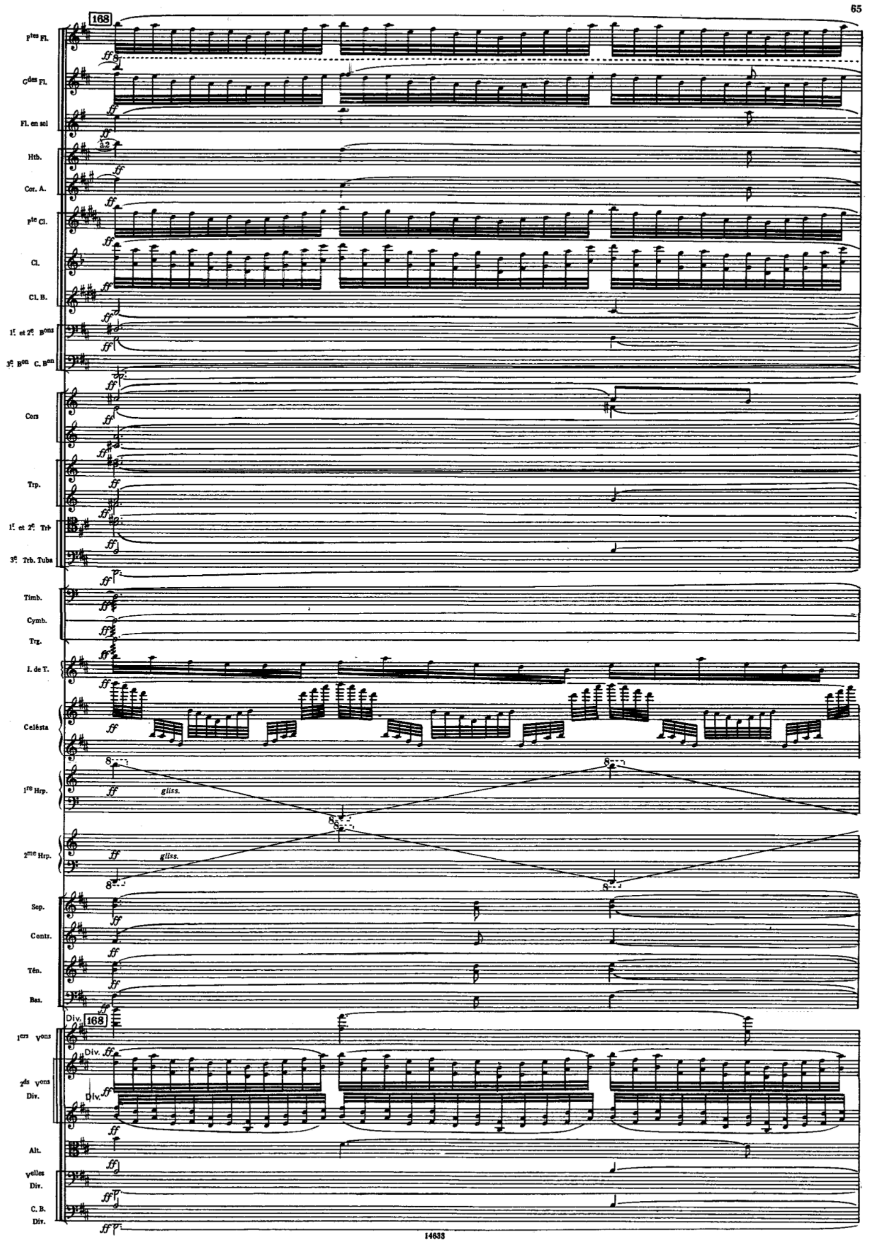
Spectromorphology

Tristan Murail expanded upon these ideas, treating musical form in terms of dynamic trajectories of timbre and density, transforming sound continuously to produce movement and structural coherence without conventional rhythm or thematic development (Murail, 2005). Murail highlights the dynamic evolution of spectra as central to form: "Whatever the nature of the spectrum - harmonic, inharmonic, linear, non-linear - the most important thing is for these spectra to evolve over time: to become more or less rich, enhance their harmonicity or inharmonicity, linearity or non-linearity" (Murail, 2005, p. 143). The phrase "more or less rich" implies variations in spectral density, meaning the concentration of frequency components within a sound spectrum, which shapes the perceived thickness or brightness of timbre.

A similar perspective arises in composer and theorist Denis Smalley's concept of *spectromorphology*, which analyzes how transformations in spectral and event density create perceived movement in electroacoustic music (Smalley, 2001). Motion (explored further below) in this context is shaped not only by the accumulation of sonic material across frequency, space or time, but also by the internal complexity of individual sounds. A single sustained tone that gradually brightens in timbre, grows louder, fluctuates in pitch or develops other internal modulations may give the impression of acceleration or intensification without increasing the number of discrete onsets. Smalley refers to such effects as spectromorphological motion, emphasizing how spectral flux, dynamic inflection, and spatial evolution contribute to perceived activity, thereby shaping the listener's experience of musical speed even in the absence of discrete rhythmic events.

Density comparison

Event counts alone - whether by onsets or spectral richness - cannot account for the perception of speed, since factors such as rhythmic regularity, phrasing, articulation, dynamic shaping, pitch usage, gestural embodiment, and microtiming also all contribute (Leman & Maes, 2014; Iyer, 2002). What matters is not only the number of events but also how they are distributed, grouped, and shaped within a musical context. A strictly numerical view of density fails to capture the more nuanced perceptual and expressive qualities of temporal flow. Consider the perspective of density on two contrasting musical examples. In a 1959 lecture, conductor and composer Leonard Bernstein noted that the first 75 seconds of Ravel's *Daphnis et Chloé*, *Suite No. 2* (1912) for orchestra contain 16,206 notes (Bernstein, 1966, p. 29). Following the logic of calculating density as notes over time, this yields an average of 216 notes per second - far exceeding the auditory flutter fusion threshold of around 20 iterations per second, beyond which discrete repetitions are fused into a continuous stream (Besser, Duncan, & Quilliam, 1966, p. 751; Moore, 2012, pp. 60-61). Yet the music does not resemble a buzzing tone. This is because the events are highly differentiated in pitch, duration, timbre, and articulation, distributed across instrumental families, and not repeated. Despite a constant flow of 32nd notes, slow-moving melodies, octave unisons, spacious harmonic pacing, and large-scale phrasing dilute the experience of rapid activity, along with, for example, the intentional blurring of harp and celesta material into shimmering textures, the overlapping entrances of winds and strings, sustained pedal points in the low register, and gradual dynamic swells that smooth transitions between otherwise dense passages.



Example 2.29. Ravel, *Daphnis et Chloé, Suite No. 2*, score excerpt. [Audio](#).

By contrast, in my solo flute piece *Torrent* (2011), approximately 2,170 notes unfold over 4 minutes and 22 seconds, averaging around 8 notes per second.[12] Though far less dense by the numbers, *Torrent* may give a more immediate impression of a faster speed.[13] The absence of periodic reference points - whether in pulse, phrasing, note material, harmonic rhythm, or meter - produces a sense of urgent, unpredictable activity. Although the piece consists of a single melodic line, its frequent alternation of arpeggios, scales, and registral leaps undermine any stability. The continual transformation of these parameters intensifies the sense of chaotic, irregular phrasing, allowing a relatively modest temporal density to convey a highly kinetic and volatile character.

[12] Chapter 5 delves further into the density of notes in *Torrent*.
[13] *Torrent* is further explored as a case study in Chapter 5.

Example 2.30. *Torrent*, score excerpt. Audio excerpt.

Taken together, these examples show that numerical note counts cannot be equated with perceived speed: the multi-layered orchestral texture of *Daphnis et Chloé* and the single-line texture of *Torrent* organize density in fundamentally different ways. I illustrate this contrast visually with a recent experience on the train between Utrecht and Amsterdam.

Example 2.31. Train from Utrecht to Amsterdam, video.

In this scene, the hedge closest to the train appears to race past at great speed, while successive layers of trees and buildings in the distance move progressively more slowly. The rapid hedge evokes both *Torrent's* racing quality and the fastest notes of *Daphnis et Chloé*, while the slower-moving layers in the background suggest the broader trajectories of the musical and instrumental layers in Ravel's composition. In *Daphnis et Chloé*, the attention may shift between these layers, creating changes in perceived temporal speed and altering the phenomenological experience of motion. By contrast, *Torrent* lacks harmonic reference points or vertical layering, removing this dimensionality and producing an intense, immediate perceptual field focused entirely on the rapidly shifting present. This demonstrates that density alone cannot explain our experience of speed; rather, it is one element among several, including the interaction of multiple musical layers, that also shape the listener's perception of temporal flow.

Changes in density

Although the differences are quite clear in both examples, it is important to note that the density in both remains relatively static. While instrument families come and go during these 75 seconds of *Daphnis et Chloé*, the combination of fast 32nds with longer note values is constant, creating relatively little change in the speed of articulated notes. The same holds for *Torrent*: the notes are generally fast with slight speed fluctuations throughout.[14] This continuity in density offers a contrast to Tenney's observation at the beginning of this section, which invites a shift in focus from static measures of density to the perceptual salience of changes in density. A gradual accumulation of events, even without a tempo change, can evoke acceleration by filling time more tightly through added subdivisions, rhythmic activity, or increasingly dense figuration. Conversely, a thinning of events can suggest deceleration or suspension. In this sense, density is not only the result of what appears on the compositional surface, such as the number of events, but also functions as an active agent of temporal experience. It can shape the perception of motion and musical speed in its own right, guiding how listeners sense acceleration, suspension, or deceleration, even when tempo itself remains constant. For example, in my composition *The Speed of Time* (2014), changes of density within equal metrical spans create the impression of acceleration or suspension.[15] When tuplets and layers increase over successive cycles, the listener perceives a quickening even though the underlying tempo remains fixed. When those elements reduce, the effect is one of slowing down or suspension. In this way, density, as the outcome of compositional tools such as tuplet variation, becomes itself a means of shaping temporal experience beyond what tempo alone can provide.

Example 2.32. *The Speed of Time*, score and video example.

Conlon Nancarrow's *Study No. 21 (1960)* for player piano is a striking example of how note onsets articulate a constantly changing density. Through the inverse interplay of increasing and decreasing speeds in the two voices - concentrated within the upper and lower registers - the work creates shifting layers of temporal density that continually reshape the listener's perception of motion. Xenakis pioneered a more explicit application of density by employing statistical and stochastic techniques to shape sound into evolving textural masses. In works such as *Metastaseis* (1953–54) and *Pithoprakta* (1955–56), Xenakis treated vast numbers of individual sonic events collectively, creating dense clouds or swarms of sound that shift gradually in density and intensity, thus generating a palpable sense of motion and transformation (Harley, 2004, pp. 10-42). Inspired by natural phenomena like the sounds of rainfall or cicadas, he conceived musical form as an aggregate of microscopic events organized through probabilities, describing it as a "plastic mold of time" (Xenakis, 1992, p. 9). By deliberately controlling the density of these events, Xenakis introduced continuous textural transitions, shaping musical time and motion independently of conventional melodic or rhythmic structures.

In my own compositional practice, density is not usually treated in numerical or statistical terms but as a set of perceptual and expressive qualities that serve the shaping of larger formal trajectories. Rather than calculating the number of events per time unit, I conceive of density in terms of relative sparseness or saturation, with infinite gradations between them. These gradations are not incidental but are explicitly composed, functioning as structural markers and energetic pivots across the span of a piece. Sections of contrasting density - whether abrupt or gradually morphing - form an essential framework through which speed, tension, and character evolve. Three sections in my work *Urban Turban* (2001) for marimba duo illustrate how different applications of the rhythmic tools can lead to different densities. In the first section, from rehearsal letters A to F, tuplets, groupings and tempos function as the main structural elements for the

[14] Speed fluctuations as a result of a tactile and embodied approach to playing an instrument is a topic explored further in Chapter Five.

[15] *The Speed of Time* and Nancarrow's *Canon X* are also explored in relation to temporal resolution in this chapter.

speeds of notes, which in combination with the other available parameters in music - such as pitches, harmony, articulations - create the phrases.

Example 2.33. *Urban Turban*, A to F, score and audio excerpt.

The 2nd section, from F to G, is characterized by long silences, articulated by sharp single notes placed sporadically, creating a sharp contrast in density after the "busy" opening section.

Example 2.34. *Urban Turban*, F to G. Audio excerpt.

The third example is a systematic diminution section in which density intensifies by keeping the number of notes constant while gradually compressing them into shorter metric spans. Over 24 bars, 12 eighth notes are progressively transformed, one by one every two bars, into 12 sixteenth notes. This process results not simply in more notes, but in an audible quickening: the same material occupies increasingly less temporal space, creating the sensation of acceleration and heightened motion.

Example 2.35. *Urban Turban*, J to L. Audio excerpt.

These approaches demonstrate how density acts not merely as texture but as a dynamic structural element in my compositional language. Density becomes a formal force, aligning with Tenney's emphasis on the rate of change in density as a crucial parameter, rather than its absolute value.

Motion

While temporal density is often deliberately produced through compositional and notational techniques, the experience of speed can emerge through other means than only fluctuations in event saturation. The missing element is directionality – the sense that something is going somewhere. In philosophical terms, this recalls the Zeno's Arrow paradox (Huggett, 2024): a sequence of discrete positions – or in this case, musical events – does not amount to perceived motion unless there is continuity and transition binding them together. That is, individual events may be numerous and dense, but without their shaping into a continuous flow, they remain static points rather than contributing to an impression of speed (Meyer, 1956, pp. 92-93; Huron, 2006, p. 306). This distinction prepares the ground for understanding motion as a perceptual construct that goes beyond density and engages with how sound events generate directionality over time.

Motion can be understood as the sense of change unfolding through time, whereas density designates a condition that may be either static or changing. Density contributes to the perception of speed, but motion arises through the way events are connected, transformed, and shaped across time. Without such shaping, even a dense succession of events may fail to convey speed; what generates it is temporal connectivity – flow, evolution, and transformation – which affords direction and momentum (Epstein, 1995, p. 7; Clarke, 2005, p. 42). In musical practice, motion is articulated through gestural phrasing, timbral and dynamic inflection, articulation, microtiming and rhythmic placement, pitch trajectory, and rhythmic tools such as tempo, rhythmic patterning, and tuplet structures. At the gestural level, this often takes the form of motive articulation, development, and sequencing that project direction and rate of change. These parameters guide propulsion and anticipation and explain why saturated textures can feel suspended while sparser materials can propel, as in the *Daphnis et Chloé* and *Torrent* examples.

Human Motion

Further, musical motion is intimately tied to embodied cognition and physical response. Music is not a purely abstract sequence of sounds but an invitation to bodily engagement. As musicologists Rolf Inge Godøy and Marc Leman argue, "music is basically a combination of sound and movement, and music means something to us because of this combination" (Godøy & Leman, 2010, p. ix). This perspective highlights how listening itself entails kinesthetic involvement, whether overtly in the form of dancing, tapping, or swaying, or covertly through an internalized imagery of motion. Within this embodied dimension, music theorist Arnie Cox's mimetic hypothesis suggests that "part of how we comprehend music is by way of a kind of physical empathy that involves imagining making the sounds we are listening to" (Cox, 2011, p. 2). Such mimetic motor imagery anchors the perception of sound in the sensorimotor system, turning listening into a form of participation. This aligns with the ubiquity of listeners' spontaneous movements to music, from subtle bodily entrainment to small gestures that reveal the body's constant involvement in listening.

Building on this, musicologist Patrick Shove and psychologist Bruno Repp emphasize that musical motion can be heard as "audible human motion," pointing to how "the sense of motion in music is grounded in our embodied awareness of the physical actions that generate sound" (Shove & Repp, 1995, p. 56). Their formulation makes clear that musical sound is always a trace of exertion - bowed strings, breath, or percussion strokes - and that listeners' responses, whether bodily movement or internal simulation, are inseparable from this awareness.

Motion in music also involves anticipation, understood as the expectation of what is to come and the preparation it invites. One way anticipation manifests is through entrainment, the listener's capacity to align bodily rhythms with musical patterns (London, 2012). Meter is not a fixed grid but a projection that emerges dynamically through embodied engagement (Hasty, 1997). The psychology of expectation adds a complementary perspective, proposing that music's emotive power lies in its ability to "reinforce accurate prediction, promote appropriate event-readiness, and increase the likelihood of future positive outcomes" (Huron, 2006, p. 4). Thus, motion is not only mimetically simulated but also temporally projected, blending bodily empathy with predictive cognition.

Importantly, musical motion must be situated within cultural contexts of bodily practice. Jazz pianist Vijay Iyer critiques the dominance of Western music discourses because they privilege pitch and harmonic relations as primary bearers of musical structure and meaning, while tending to marginalize the embodied and temporally inflected dimensions through which many musics are organized. He stresses that "the status of the body and physical movement in the act of making music" varies across traditions, and he offers African-American groove as a case where musical coherence, motion, and felt speed arise through embodied microrhythmic inflection, inseparable from dance and ritual (Iyer, 2002, p. 388). His account underscores that embodied cognition is culturally constructed and situated, and it therefore cautions against Western music discourses presenting their preferred analytic emphases as universally valid.

These ideas complement the LEMI model and the theory of situatedness in the section Listener–Environment–Musical Stimulus–Interaction model and Situated Knowledge, clarifying that what is perceived as motion in music emerges from affordances and constraints distributed across listener, environment, music, cultural background, and their ongoing interactions. In performance and composition, I treat the body as the primary locus where motion is specified and tested: I play and sing materials to assess how they project propulsion, suspension, acceleration, or deceleration through parameters such as phrasing, articulation, dynamic shaping, microtiming, pitch trajectory, and rhythmic structures, as outlined above. Listening to try-outs, whether live or computer-generated, provides real-time feedback about perceived motion and speed; these try-out sessions (short repeated cycles of playing, recording, and listening) function as iterative filters that guide decisions based on how the musical material is physically felt, motorically enactable, and auditorily traceable in the moment - that is, followable as a coherent stream of sound events as they unfold in real time.

Taken together, these perspectives suggest that motion arises from the interplay of sensorimotor simulation, entrained anticipation, and culturally learned movement. The next section specifies how this coupling unfolds across micro, meso, and macro timescales.

Timescales

To clarify how bodily sensations of musical motion arise from sound, it is helpful to consider three concurrent timescales of activity. In both music theory and cognition, scholars have proposed many ways of conceptualizing timescales, from acoustically defined durations to perceptual thresholds and formal structures. A particularly useful baseline is Godøy's model of three interrelated and concurrent levels that co-express in any sounding event: the micro timescale (less than about half a second, encompassing attack and onset detail, spectral flux, vibrato cycles), the meso timescale (approximately half a second to five seconds, where perceptually coherent gestural "chunks" such as a bow stroke, breath, hand motion, note or chord onset, or the articulation of a motive or small phrase emerge), and the macro timescale (longer than about five seconds, comprising phrases, sections, and formal arcs) (Godøy & Leman, 2010, p. 121; Godøy, 2018). At the macro level, traditional and contemporary designs (e.g., sonata, rondo, spectral or modular forms) generate long-range trajectories of tension and release through thematic, harmonic/timbral, and textural change, shaping expectation (Meyer, 1956; Lerdahl & Jackendoff, 1983). In the *Daphnis et Chloé* example discussed above, such macro shaping governs the long span of swell and release that shapes a slow felt pace. At the meso level, local pitch trajectories, motivic development, voice leading, and cadential gestures articulate continuation or closure; in *Torrent* the lack of stable periodic reference points and the continual alternation among arpeggios, scalar runs, and wide registral shifts generate restless, breath-shaped gestures that drive perceived propulsion. At the micro level, attack shape, expressive microtiming, and fine-grained rhythmic/spectral articulation modulate the moment-to-moment energy of perceived motion; in both *Daphnis et Chloé* and *Torrent*, the timing of individual notes makes this micro shaping audible.

While this tripartite model maps sensibly onto musical structure and performance, it should be treated as a heuristic model whose boundaries are permeable. These temporal levels also intersect with the earlier distinctions between motif, phrase, and gesture: whereas motif, phrase, and gesture name the type and character of material, micro, meso, and macro specify the timescales on which such material is perceived and organized. A motif typically resides at the meso level but is inflected by micro-level details; a phrase usually belongs to the macro level, though articulated by meso-level gestures; and a gesture may traverse more than one scale depending on its contour and energy. In this way, the motif–phrase–gesture distinctions and the micro–meso–macro timescale model reinforce one another without collapsing into a single system.

Taken together however, the three timescales explain how musical motion is co-constructed across levels. Micro-level articulations condition the felt propulsion of meso-level gestures; sequences of meso-level gestures scaffold macro-level trajectories of expectation and release; the macro frame, in turn, recontextualizes the same micro cues as energizing or suspending depending on their placement. Thus the perception of speed is a byproduct of cross-scale coupling: changes in attack shape or spectral flux can alter the drive of a gesture, which can reorient the long-range sense of pace even when one layer of temporal density, such as tempo, remains fixed. This cross-level interaction also allows apparent contradictions, such as high event density that feels static or sparse textures that feel urgent.

Accordingly, this dissertation focuses on the micro and meso timescales in Chapters 2, 3, and 4, where performative action and the practical tools of speed most directly shape momentary experience. At these levels I specify, test, and notate motion through gestural phrasing, timbral and dynamic inflection, articulation, microtiming and rhythmic placement, pitch trajectory, and notated devices such as tempo, rhythmic patterning, and tuplet structures. The macro timescale enters where questions of form and large-scale pacing are at stake, but because it brings additional variables such as narrative, linearity, memory, and sectional design, it remains outside my central analytical focus except where sequences of meso-level gestures scaffold macro trajectories.

2.4 Smooth and Striated Time

Discussions of speed in music often begin with the established framework of tempo, which presumes a steady pulse. However, not all music is governed by pulse; in such cases, speed becomes less defined and more fluid. Many concerto cadenzas, for instance, unfold "out of time," with phrases articulated freely and without a continuous beat. Rubatos and irregular pacings introduce a floating, flexible sense of motion, and the measured flow of time may seem to pause altogether. These contrasts reveal two broad tendencies in musical temporality: one rooted in regularity and metric stability, the other in irregularity and temporal freedom. In the terms developed by Pierre Boulez and Ivan Wyschnegradsky and later expanded by Gérard Grisey, *striated time* refers to musical time organized into regular, countable units such as pulses, measures and tuplets, whereas *smooth time* designates a more irregular, non-metric temporality in which events are not bound to a stable grid (Boulez, 1975, pp. 83–90; Wyschnegradsky, 1927, p. 144; Grisey, 1987, p. 244). Central to this section is the question of how these two temporal modes shape the articulation of speed in composed music, particularly through notation, temporal organization and the interaction of musical parameters. Rather than treating smooth and striated time as oppositional categories, the discussion emphasizes their interplay and the expressive possibilities that emerge when musical materials move between or blur these temporal modes.

Although philosophical debates about the nature of time are longstanding, the specific distinction between music with and without pulse offers a particularly useful framework for examining how speed is perceived and structured in musical contexts. In 1889, French philosopher Henri Bergson famously introduced the concept of an indivisible duration to our experience of the passing of time (Bergson, 1889/2001, p. 100). Bergson argued that our actual, lived experience of time is not made up of distinct, separate units (like seconds or minutes on a clock), but rather flows continuously and qualitatively. He called this flowing experience *la durée*, often translated as *duration*. According to Bergson, duration is indivisible because we do not naturally experience time in chunks – like a stopwatch ticking – but as a smooth, ongoing process. This notion influenced later 20th-century discussions of temporality in the arts, including Stephen Kern's historical account of new time concepts emerging around 1900 that challenged mechanical, clock-based measures. These included the advent of Einstein's theory of relativity, which reframed simultaneity and sequence; the growing use of psychological time to account for subjective experience; and the influence of technologies such as the telegraph, telephone, cinema, and railway timetables, all of which altered perceptions of temporal coordination and speed (Kern, 2003, pp. 24–29).

In contrast to Bergson's notion of flowing, indivisible time, music has historically been subjected to imposed time structures, including meters, pulses, tuplets, and rhythmic units, that segment and quantify temporal experience. In his book *Music After Deleuze*, the music scholar Edward Campbell cites the composer Ivan Wyschnegradsky's 1927 formulation of this problem, calling it "the antithesis of the continuous and the discontinuous" (Wyschnegradsky, 1927, as cited in Campbell, 2013, p. 70). Wyschnegradsky framed this as a dialectical opposition in which the continuous and discontinuous remain in tension, rather than functioning as simple alternatives. A flowing legato melody, however seamless it may sound, still depends on underlying pulses or metric divisions; likewise, a fragmented, disjointed texture still unfolds across temporal flow. This fundamental tension between continuity and segmentation is central to musical time. Within this French Bergsonian context, Campbell positions Wyschnegradsky's formulations as a precursor framework, one that later microtonal work and Boulez's smooth and striated pitch space taxonomy can be read as extending and systematizing (Campbell, 2013, pp. 71–72).

Boulez extended Wyschnegradsky's framework in his 1960 Darmstadt lectures, defining these different modes of time as striated (*strié*) and smooth (*lisse*) (Boulez, 1960/1986, p. 87). Striated time is marked by its subdivision into measurable units such as beats, tuplets, and metric divisions, constituting a rhythmic grid that coordinates multiple layers. Smooth time, in Boulez's thought, designates a continuous and non-metric temporality, free from regular pulse or measured divisions, in which musical events unfold as fluid durations rather than as discrete units.

Although a substantial body of literature addresses the philosophies of smooth and striated time, the practical elaboration of how these categories operate in music and notation remains comparatively underdeveloped. Most accounts remain at a general or philosophical level, often overlooking the operative mechanisms through which these modalities interact within compositional practice. As Grisey observed, Boulez's distinction risks remaining a merely phenomenological description, adequate only for relatively simple rhythmic situations (Grisey, 1987, p. 245). Similarly, Campbell argues that while Deleuze and Guattari provide a fertile conceptual vocabulary, detailed analyses of actual musical structures and notations are often lacking (Campbell, 2013, p. 71). Thus, although the philosophical frame is well established, the practical investigation of how smooth and striated times combine and transform within music is still in its infancy.

Striated Time

While discussions of striation have traditionally emphasized pulse as its clearest representation, any regular element can articulate striation. Tuplet subdivisions, repeated timbral changes such as in a trill, or conductor gestures may all generate striation if they occur at regular intervals, regardless of the timescale. In this broader sense, any musical parameter can serve as its agent: as long as events recur regularly, striation is established. In my composition *Urban Turban* (2001), for example, the first 26 bars present a series of contrasting phrases, but striation is preserved through a consistent use of pulse, tuplets, groupings, or tempo anchoring each moment in a shared grid.

Example 2.36. *Urban Turban*, A to F, score and audio excerpt.

Beyond its utility for coordination, striation also plays a crucial expressive role. Regularity provides a backdrop for deviation, which can heighten musical impact. When a listener anticipates a note at a particular moment and it is delayed, omitted, or arrives early, that disruption can produce tension, release, excitement, or emphasis (Huron, 2006, pp. 131-141). This occurs not only on larger formal levels such as omitting an expected downbeat, but also on a microtemporal scale. Subtle shifts in timing, whether notes are played slightly before, on or after the beat, introduce a world of expressive nuances shaped by the interplay between expectation and variation.

Smooth Time

In contrast to the emphasis on striation found in much rhythmic theory, composer and music theorist Brian Hulse, drawing on Bergson's philosophy, maintains that the striated image provides an incomplete account of the qualitative, indivisible nature of temporal experience. "The striated image simply fails to capture reality - a reality that is qualitative, rich, and ultimately indivisible" (Hulse, 2016, p. 282). He positions smooth time as the fundamental temporal ground of musical experience, within which striated structures are temporarily imposed. "So even though it is clear that striation is a real thing, and relevant to process, smooth space is the milieu it inhabits, in which it draws and redraws its organizing power" (Hulse, 2016, p. 283). Metric frameworks - such as pulses, tuplets, and rhythms - thus appear not as foundational structures but as imposed grids that emerge from and return to a broader, continuous temporal field, much like how human timekeeping carves seconds and minutes from the seamless flow of lived time.

Smooth time, in this sense, resists the predictability and segmentation typical of striated time. It arises from the irregular placement of events in time, whether through differing intervals between onsets (irregular rhythms) or through performer interventions such as rubato, fermatas, and expressive timing. For Boulez, smooth time consists of durations that unfold without rigid metric subdivision, forming a temporality that is shaped dynamically rather than dictated by preexisting grids (Boulez, 1971, pp. 88-89). Hulse similarly describes this quality as an "untamed lawless flow of intensities" (Hulse, 2016, p. 282), emphasizing its expressive and continuously evolving nature. In this view, smoothness refers not to the absence of structure but to a mode of temporal articulation in which gestures and sounds unfold according to their own internal pacing, resisting quantization and embracing a continuity that defies regular segmentation.

While I agree with Hulse that smooth time reflects our default experiential mode, my practice as a composer and performer has shown me that the rhythmic grid holds value beyond coordination and organization. It enables the articulation of an infinite variety of meters, tuplets, rhythms, and, ultimately, speeds. These structures, far from restricting musical expression, open up distinct expressive possibilities that would not emerge from purely free-flowing time.

The following musical examples illustrate how smooth time can be expressed through various compositional and performative strategies:

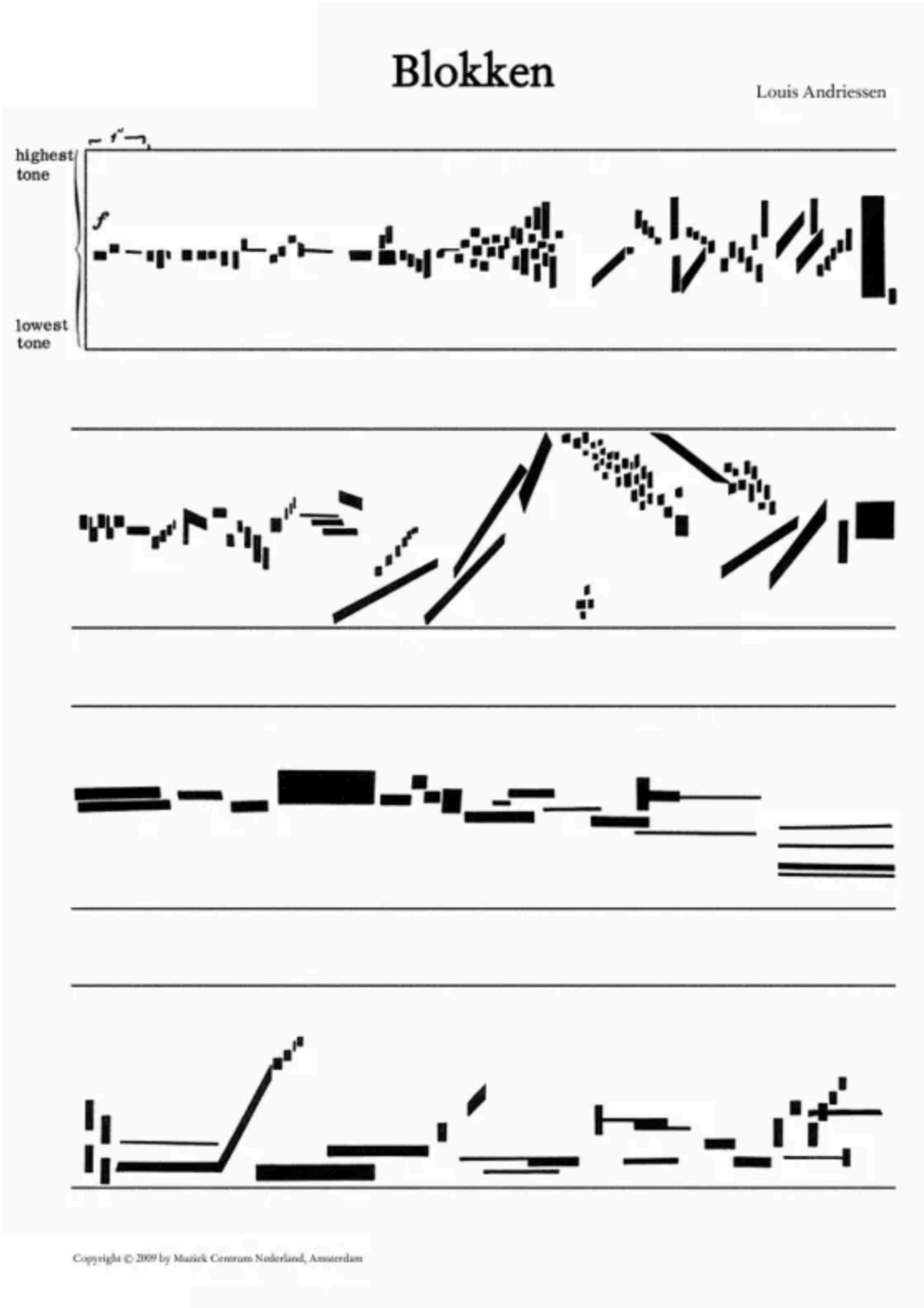
Example 2.37. Igor Stravinsky, *Pétrouchka* (1911), flute cadenza, score excerpt. Video excerpt.

While the three-note motives (from the pick-up to the second bar) give small moments of regular speed, each fermata stops the flow, at the discretion of the flutist. As will be discussed further below, Grisey found Boulez's theory limited, stating that "such distinctions between [smooth and striated time] only assume a phenomenological value in a limited number of cases [...] only short and simple rhythmic cells would make such a classification possible" (Grisey, 1987, p. 245). While the Stravinsky example illustrates Grisey's point that only simple rhythmic cells may allow for a clear phenomenological distinction between smooth and striated time, these rhythmic cells do also offer a uniquely transparent opportunity to observe how localized regularity can briefly emerge and then dissolve. By examining how such brief striations interact with a surrounding smoothness, it becomes possible to develop a more nuanced understanding of how these temporal modes can coexist and inform the experience of speed and structure in music.

Another example of smooth time appears in my composition *Alap* (2005). Although the rhythms are notated within a clear metric framework, I intentionally employed rubato and fermatas to create temporal flexibility. These devices invite the performer to shape time responsively, loosening metric regularity and enabling a temporal flow that unfolds according to expressive intent rather than fixed alignment. This use of elasticity within a measured structure exemplifies how smooth time coexists with and within metric notation when temporal flexibility is foregrounded.

Example 2.38. *Alap*, score excerpt. Audio excerpt.

Smooth time is not limited to gentle or subtle textures. Loud, energetic musical gestures can also exist within a temporally smooth context, as can be demonstrated by Louis Andriessen's piano piece *Blokken* (1966). In this piece, graphic notation replaces conventional metric structure, and timing emerges from the performer's interpretation of visual shapes. Such notations remove the rhythmic grid, allowing time to unfold according to the contour and trajectory implied by each graphic shape rather than predetermined intervals.

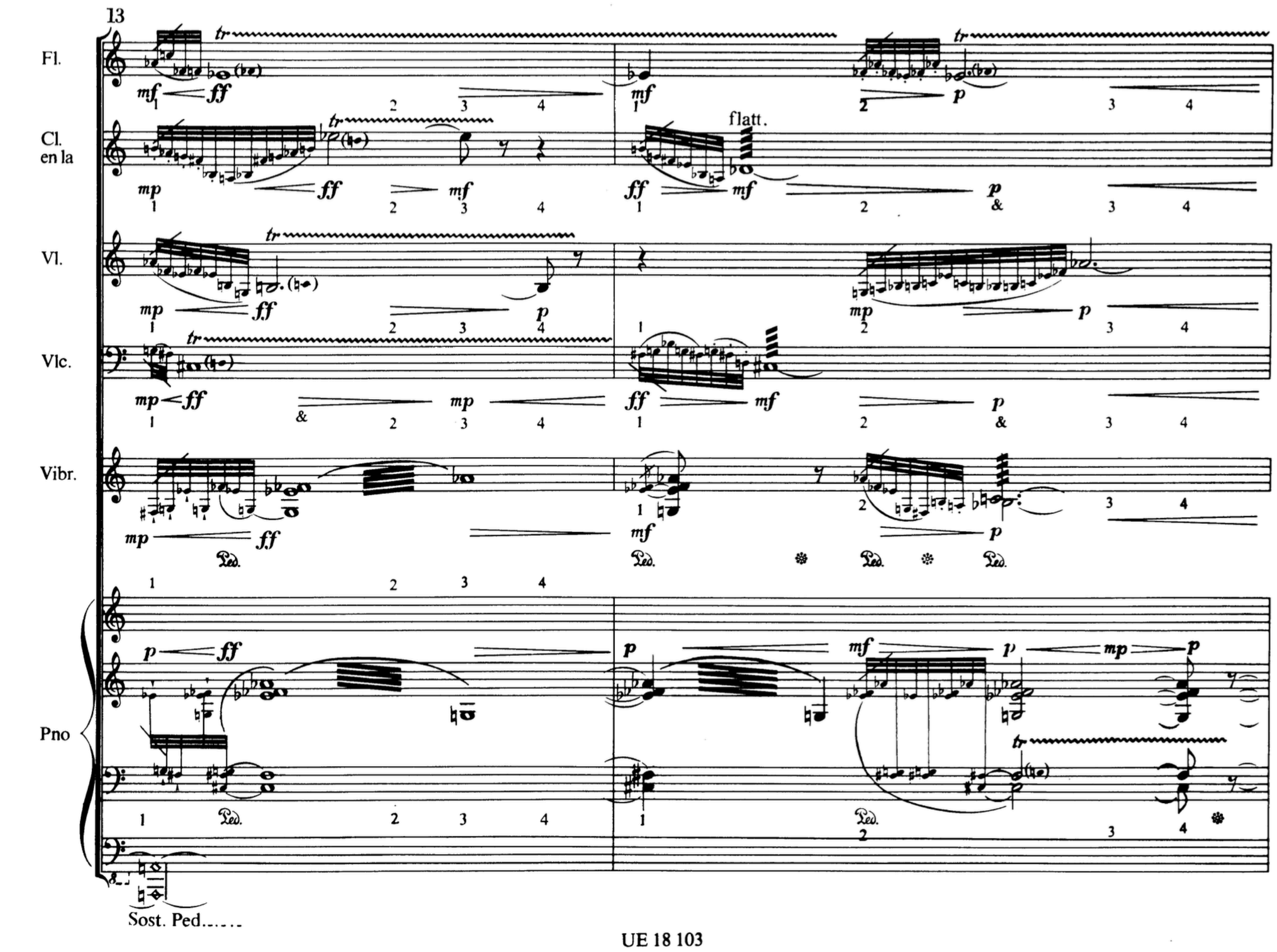


Example 2.39. Andriessen, *Blokken*, score excerpt. Video.

Interplay

While the binary distinction or opposition between smooth and striated time offers a helpful framework, it is inherently a simplification. As both Wyschnegradsky and Boulez pointed out, musical time rarely exists in purely one form or the other. Most music blends these modalities, shifting fluidly between them or reflecting them differently at different timescales. For example, in the *Pétrouchka* cadenza discussed above, brief moments of metric regularity emerge and dissolve sequentially at the meso timescale while the macro phrase offers a broader temporal flexibility. These perspectives reveal the dynamic interplay between striation and smoothness, especially when considered over different musical spans.

An illustrative multi-layered example of the interplay between smooth and striated time can be found in the opening section of Boulez's ensemble piece *Dérive I*, marked at a tempo of 40 bpm with the indication *Très lent, immutable* (very slow, unchanging). In this passage, various instruments enter with runs of grace notes starting on the beat, but each run varies in length. While the initial grace notes introduce a sense of regularity - anchored to a consistent metric pulse - their differing durations lead to long notes beginning at unpredictable moments. This results in a surface texture that feels fluid and temporally unstable, even while underpinned by an underlying grid. The layering of steady entrances with varied expressive trajectories generates a smooth temporal quality within a striated framework.



Example 2.40. Boulez, *Dérive I*, score excerpt. Audio excerpt.

Returning to *Urban Turban*, at bar 27 the striated texture abruptly dissolves into silence. These notated silences are occasionally punctuated by unison attacks, but otherwise contain no regular articulations. The absence of pulse and rhythmic activity creates a series of "frozen moments," each varying in duration. With no consistent event density or periodicity, the music enters a temporally smooth domain - one in which time is no longer measured through regular intervals but instead stretches and contracts unpredictably according to the placement of sparse gestures.

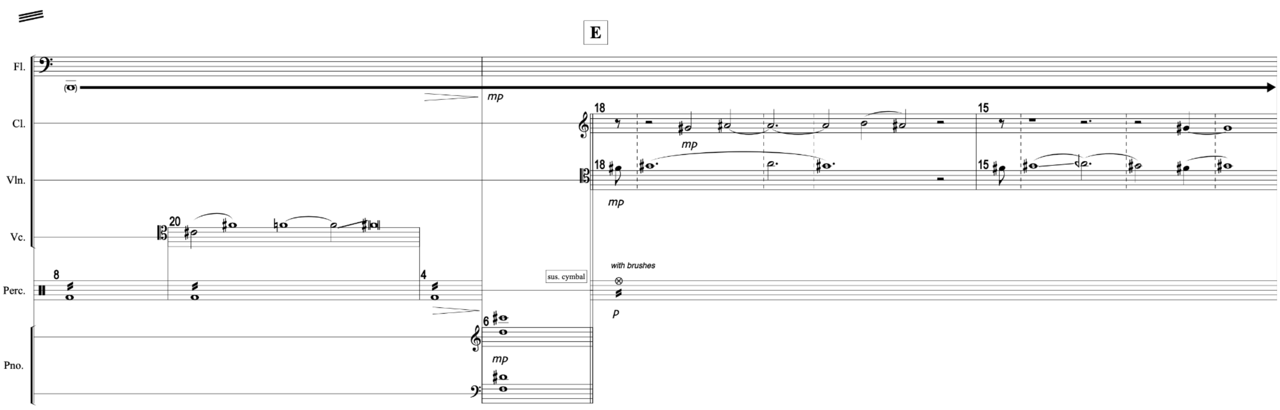
Example 2.41. *Urban Turban,* F to G. [Audio](#) excerpt.

To execute the silences in *Urban Turban* with precision, performers must rely on an internalized rhythmic grid. This creates a striking contrast between the temporal experience of the performers and that of the audience. While listeners perceive a suspended, floating temporality, the performers are mentally tracking pulse and duration with exactness. Pianist Philip Thomas describes this divergence as fundamental to any performance: "[T]he experiences of listeners and performers are different - where the listener may hear pitch, the performer may be focused upon matters of physiology; where the listener may be aware of time suspended, the performer may be counting furiously; where the listener hears a single gesture, the performer may be concerned with combining a number of disparate strands" (Thomas, 2022, p. 98).

As both a listener and composer, I find that performances of *Urban Turban* are most effective when no visible cues are given to indicate pulse or attack. This lack of external coordination enhances the sense of temporal suspension and fosters a seemingly magical alignment among the musicians - a perceptual illusion grounded in a rigorous internal structure.

As described in the Introduction, *Sound Becomes Visible in the Form of Radiance* opens with long, sustained tones whose durations are notated in seconds. This results in a dense, immersive texture with minimal change or articulation - no clear events occur to punctuate time. Although the performers maintain a steady internal tempo of 60 bpm, establishing a latent striated framework, the lack of surface-level regularity allows the music to unfold with a smooth temporal character. As with the silent metric grid in *Urban Turban*, the structure remains perceptually hidden. The specification of time in seconds points to an underlying grid, but the surface experience is one of continuity and temporal suspension where duration is measured, but not divided.

In *Sound Becomes Visible in the Form of Radiance*, an example of smooth and striated time coexisting occurs at letter E, where a layer of regular, articulated events is introduced over the otherwise static and sustained texture. This insertion of measured, periodic material into an ongoing field of non-metric sound illustrates the placement of striated spaces within smooth time. Rather than transitioning from one mode to the other, both temporalities run in parallel, highlighting their contrasting organizational principles within the same musical moment.



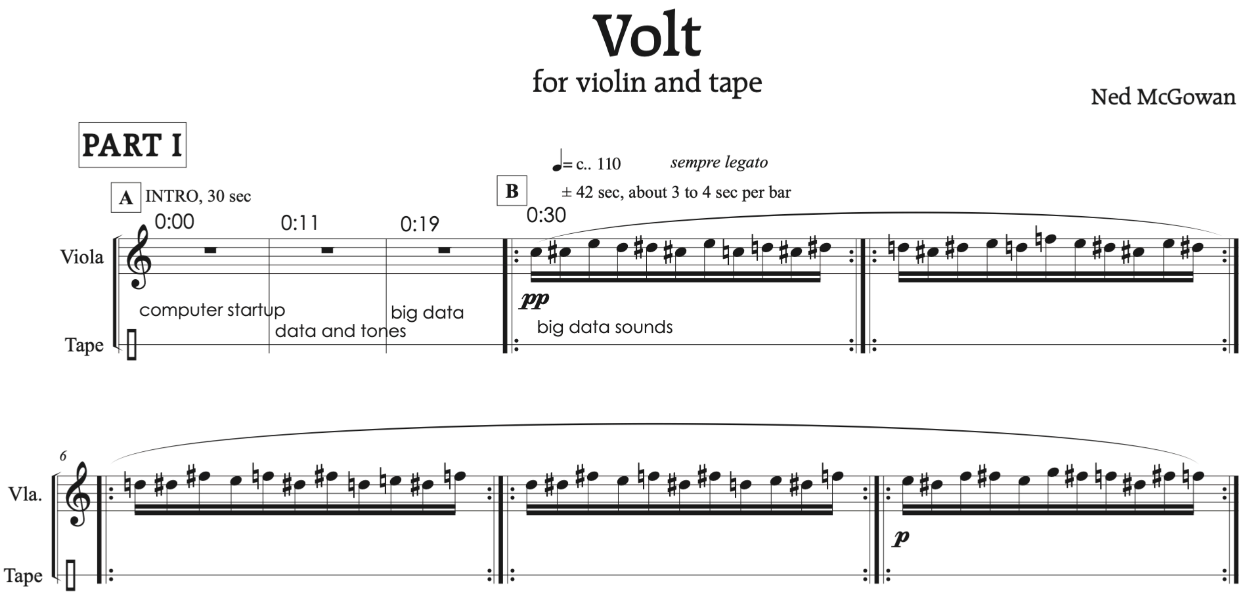
Example 2.42. *Sound Becomes Visible in the Form of Radiance*, score excerpt. Audio excerpt.

John Cage's *Five* (1988) for five performers (the instrumentation is indeterminate), one of his *Number Pieces* (1987–1992), exemplifies two distinct strategies for temporal indeterminacy within a smooth time framework. In the first system, performers are given time brackets within which they are free to begin and end a note - in this example a C# - allowing for temporal fluidity and individualized pacing. In the other, precise start and end times are specified, but the length of the notes and the location of the breath remain undetermined, left to the performer's discretion. In both cases, Cage establishes a framework of temporal structure without regular metric subdivision. The result is smooth time: musical events unfold without predictable spacing, shaped by performer choices within broadly defined limits.

Example 2.43. Cage, *Five*, score excerpt.

This approach builds on Cage's earlier exploration of durational frameworks, most famously in *4′33″* (1952), where the act of specifying durations without content invites a reconsideration of musical time itself. In the *Number Pieces*, Cage refines this idea by balancing structure and freedom: clocktime frames coexist with smooth, non-striated articulations. The indeterminacy introduced by the performer's agency becomes a generator of expressive elasticity, eroding regular pulse while retaining a latent temporal grid.

As in *Radiance*, my composition *Volt* also explores the coexistence of smooth and striated time. In this case, smooth time is conveyed through dense, noise-like microchip textures,[16] which are set against a contrasting layer of slower, clearly articulated sixteenth notes in the violin.



Example 2.44. *Volt*, score excerpt. Audio excerpt.

[16] By "microchip textures" I mean actual sounds generated by the physical operation of microchips and electronic circuits – the hums, clicks, and electromagnetic emissions that leak into the audible spectrum as a by-product of their functioning. This differs from sounds synthesized inside the computer's software or digital signal processing, which are the result of intentional coding. Microchip textures are, in effect, the acoustic residue of computation rather than the programmed output of computation.

De Snelheid (1983) by Louis Andriessen — usually translated as *The Velocity*, though snelheid also carries the meaning of "speed" — offers a sustained and structurally explicit engagement with the interplay of smooth and striated time. The piece takes the perception of speed as its compositional subject, constructing multiple simultaneous temporal strata, each occupying a different position on the smooth–striated continuum and each executing its own accelerando at a different rate.

Example 2.45. Andriessen, *De Snelheid*. Audio (part 1/2) and audio (part 2/2).

The most explicitly striated layer is the woodblock pulse, played by two dedicated percussionists and functioning as the primary temporal anchor of the entire piece. The woodblock players drive the work's systematic acceleration through varied combinations of meters and tempi, producing a surface of maximum metric definition: short, percussive, precisely placed events with no ambiguity of onset. Andriessen identifies this pulse as the most important voice in the piece; the other layers are defined largely by their relationship to it (Andriessen, 2002, p. 176).

The two identical wind orchestras — each comprising saxophones, trumpets, trombones, tuba, and piano, positioned on either side of the ensemble — form a second and third layer that follow and respond to the woodblock acceleration. They carry out hocketed passages of varying lengths in phrases, so that while their rhythmic material is grid-based, the irregular phrase lengths and the shifting hocket patterns between the two groups introduce a degree of unpredictability at the meso timescale. Each phrase is internally striated, but the relationships between phrases are less predictable, placing these layers at an intermediate position on the continuum. The harmonic speed of the wind ensembles increases throughout the work, adding a further dimension of acceleration to their already complex temporal profile.

The fourth layer is the central percussion: bass drum and tomtoms playing a slow march throughout the entire piece, which Andriessen describes as "the Buddha" (Andriessen, 2002, p. 176). This layer maintains a slow-paced regularity from beginning to end: striated, but at a rate so slow and so widely spaced that its relationship to the fast woodblock layer is more one of contrast than coordination. The Buddha's regularity is not absolute: rhythmic irregularities within the slow march introduce a quality that edges toward smoothness, so that despite its underlying grid this layer is less tightly striated than the woodblocks. Andriessen uses a series of metaphors for it — bellows, a breathing body, a sleeping giant — all of which suggest an organic, slightly imprecise regularity rather than mechanical precision. In the terms developed earlier in this section, the Buddha occupies a position analogous to the performer's internalized metric grid in *Urban Turban*: structurally striated but perceptually closer to smooth time, particularly in contrast to the explicit striation of the woodblocks.

The fifth layer, carried by the third orchestra of flutes, electric harps, bass guitar, and hammond organ, maintains two distinct temporal identities. The first identity consists of long melodic lines and sustained harmonies whose pacing is largely indifferent to the acceleration proceeding in the other layers: the melodies unfold in broad, unhurried phrases, and the harmonies are held long enough to be experienced as durations rather than events, producing a temporal experience closer to Bergson's *durée* than to metric striation. The second identity is made up of short chords, often articulated in response to the hocketing phrases of the wind ensembles, introducing a more event-like quality without approaching the rapid striation of the woodblocks. Although the harmonic speed of both strands remains largely slow throughout, what anchors this orchestra toward the smooth end of the continuum is not its slowness but the irregularity of its durations and its lack of regular metric reference points — qualities that persist even as the surrounding layers accelerate.

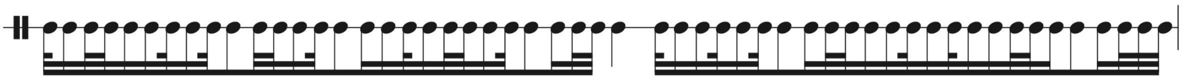
What makes *De Snelheid* a uniquely concentrated demonstration of the smooth–striated interplay is that all five layers are simultaneously present throughout the work, each at a different position on the continuum — from high striation of the woodblocks to the broad smoothness of the sustained melodies — and each following its own accelerative trajectory at a different rate. Speed here is not a single metronomic value but a field of simultaneous, partly independent temporal identities whose interaction produces an experience that no single layer could generate alone.

Rhythm

Many of the examples so far have juxtaposed layers of smooth and striated time, yet a single musical layer can also embody both. Notated rhythm demonstrates how this occurs: when rhythmic values remain consistent - such as in a string of evenly spaced sixteenth notes - striated time is reinforced through predictable temporal intervals. This regularity provides a clear sense of pulse and metric structure. However, as irregular durations are introduced, that sense of predictability begins to dissolve. Rhythmic articulation becomes less uniform, weakening the perception of a fixed grid and giving rise to a smoother temporal quality. This transformation can be understood as a shift from a rigid, metric organization to a more fluid and expressive temporal unfolding. The following example presents a sequence of evenly spaced sixteenth notes that exemplify ideal striated time:

Example 2.46. Same note length, score. Audio.

In contrast, a sequence of varied note lengths - still played at the same tempo - yields a smoother experience of time. The irregularity in rhythmic duration softens the predictability of onset intervals, reducing the sense of metric regularity and inviting a more fluid temporal perception.



Example 2.47. Irregular notelengths, score. Audio.

The second example introduces rhythmic variation without any clear structural groupings that would suggest a regular pulse. Still, brief islands of regularity do emerge - such as when three consecutive notes occur at equal intervals - momentarily suggesting striated time, as seen earlier in the *Pétrouchka* example. This subtle interplay between order and deviation highlights a continuum between fully regular and highly irregular articulation, with countless gradations in between. The perception of smoothness or striation across a longer musical passage depends not only on local rhythms but also on the scope of material being considered. The duration and scale of analysis thus become crucial in determining where a passage falls along this temporal spectrum - an issue explored further below.

The use of irregularity through changing group lengths is a technique I explore in *Rhythmic Etudes, Book 1: Blueshift* (2014).

Example 2.48. *Rhythmic Etudes, Book 1: Blueshift*, score excerpt.

The cellular groupings in the top line occupy an intermediate position on the smooth–striated continuum, combining equal and unequal note lengths. These irregular groupings are set against a stable underlying pulse in the bottom line, which articulates regular durations - half notes, quarter notes, and eighth notes. As a result, the two layers function differently: the top line leans toward smooth time due to its variability, while the bottom line reinforces striated time through its consistent metric structure.

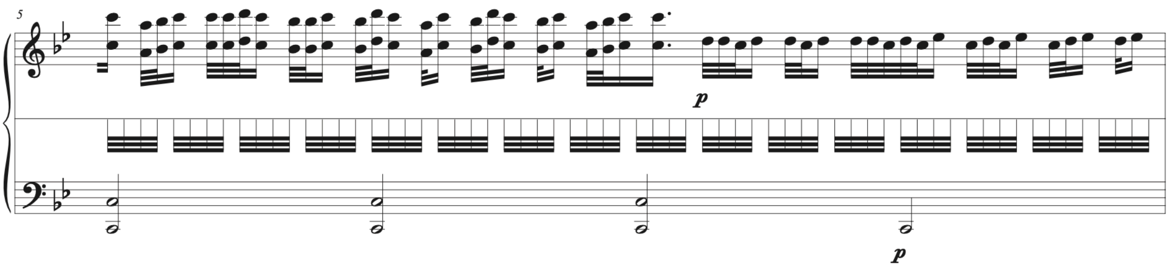
Polytempo Music

Polytempo music - where multiple tempi coexist structurally - can be seen as a systematic extension of tuplets. Although polytempo might appear inherently striated due to its reliance on rhythmic grids defined by specific tempo values, the interaction between those grids can introduce degrees of smoothness. Each individual pulse stream is striated, but their combined effect may blur temporal regularity. When the relationships between tempi are simple ratios, such as 2:1, 3:2, or 4:3, the striated structure remains perceptible. However, when the tempi are related by irrational or extremely close ratios - such as 99:100, π:1, or other complex proportions - the periodic alignment becomes imperceptible over any reasonable time span, generating a temporality that feels fluid, diffuse, and thus smooth. Importantly, the degree to which these patterns are perceived as smooth or striated is bounded by human physiological and cognitive capacities. Even when complex grids exist in the score, perceptual limits on speed discrimination, temporal resolution, and ensemble coordination mean that beyond a certain threshold the structure is no longer apprehended as patterned, but collapses into a smooth auditory field. This interplay between notated temporal grids and perceptual smoothness can be heard in my ensemble piece *Building Music* (2013).

Example 2.49. *Building Music*, video excerpt.

Implicit Striation

In composing *Blueshift* (2014), my aim was to explore the interaction between irregularity and regularity through the interplay of two distinct layers. However, if one adopts the 32nd-note subdivision as a reference grid, even the irregular groupings in the top line can be interpreted as aligning with an underlying striated framework. At this level of granularity, uneven groupings become perceptible as metrically anchored events. The choice of subdivision resolution is decisive here, since a finer grid permits more events to be captured as commensurable, whereas a coarser grid leaves some events perceptually unmoored. This illustrates how a least common denominator (LCD) can serve as an implicit temporal grid, an approach often used to coordinate tuplets or to align asynchronous layers within a compositional structure.[17]



Example 2.50. *Rhythmic Etudes, Book 1: Blueshift*, score excerpt.

The rhythmic grid maintained during the silences of *Urban Turban* and the sustained sounds of *Radiance* can also be understood as forms of *implicit* striation. In both cases, the performer keeps a precise internal count that is not directly communicated through the sounding music. This internalized temporal framework allows performers to synchronize and place events accurately, even when those events appear irregular or freely timed to the listener. From the outside, the surface presents a smooth temporal flow, but underneath, it is governed by a structured and consistent grid. This creates a notable duality: for the performer, the passage may feel rhythmically grounded, while for the listener it unfolds with the unpredictability and elasticity characteristic of smooth time.

Just as a single moment in lived time can simultaneously belong to overlapping temporal frameworks - such as seconds, minutes, hours, and days - a musical event can participate in multiple nested layers of temporal organization. For instance, a single note may function as part of a brief gesture, a larger phrase, a recurring thematic structure, and the overall form of a piece. Each of these layers unfolds at its own

[17] With tuplets, the LCD can be used to line up two layers within a striation, a practice often used to execute them correctly. See Chapter 3: Tuplets for more information.

temporal scale, and their interaction can produce striking contrasts: a rapidly articulated motive may exist within a slowly developing formal section. Even a subtle articulation or timbral shift can reverberate across these layers, influencing perception differently depending on the temporal context. This multivalence suggests that musical time is not singular or fixed, but shaped by the listener's frame of reference and the scale of attention - a concept often associated with hierarchical models of temporal structure (Phillips, 2022, pp. 1-10; Lerdahl & Jackendoff, 1983, p. 18).

These overlapping temporal layers each contribute to the perception of speed, and their interaction is one of the most nuanced aspects of musical expression. In the *Pétrouchka* cadenza above, each three-note pick-up motive introduces a moment of striation, but these are repeatedly interrupted by fermatas, producing localized episodes of smooth time. Interestingly, Stravinsky includes the instruction *ma non accel* (but without accelerating) in the tempo marking. Why caution against acceleration in a passage punctuated by fermatas, where time seems to stop? This marking suggests that, despite the interruptions, the repetitive motive can be perceived as striated when viewed at the scale of the entire phrase. If the performer places each iteration progressively closer together, an emergent *accelerando* might result - an effect Stravinsky appears to have anticipated and sought to prevent. This illustrates the coexistence of multiple types of time operating on different temporal scales, shaped both by compositional design and performer interpretation.

Microtiming

Looking towards smaller scales, microtiming in music refers to the subtle, expressive deviations from strict rhythmic timing that give a performance its feel, groove or human character. As such they can be understood as a local negotiation between smooth and striated time. By definition they operate within a metric or temporal grid, suggesting striation, yet the expressive deviations subtly undermine or bend that grid toward smoothness. These micro-deviations do not abolish the metric structure, but they do destabilize its precision, introducing a felt elasticity. Within the continuum of smooth and striated time, microtiming can be understood as fine-grained movement away from ideal striation without crossing into fully smooth time.

A comparison of timing between percussionist B.C. Manjunath and myself in a performance of my composition Cycle Games I highlights key aspects of timing and microtiming. Although our senses of pulse remain closely aligned throughout, subtle differences emerge in the phrasing and placement of individual notes within pretty much every phrase. These distinctions reveal the individualized shaping of time within a shared metric framework, illustrating how microtiming operates even in tightly synchronized contexts. In Example 2.50, around 0:18, the discrepancies are extremely subtle yet still audible as slight differences in onset placement and release timing. At 5:54, the deviations become more pronounced, yet our pulses remain together because both parts continuously recalibrate against the underlying metric cycle.

Example 2.51. *Cycle Games I*, video.

Although these differences are minor, they require us to make continual, subtle adjustments to stay synchronized - a process fundamental to ensemble performance. These moment-to-moment calibrations demonstrate how microtiming operates on a finer temporal scale than rhythm, yet remains deeply shaped by the same tension between predictability and flexibility. Within the continuum of smooth and striated time, microtiming can be seen as a site where this larger dialectic is enacted on a highly detailed, expressive level.

By considering the layering of smooth and striated time across different timescales, several conclusions arise. This perspective challenges the notion that smooth time can be neatly defined as either *irregular* through non-systematic lengths between articulations, or *indeterminate* through performer intervention such as rubato, fermatas or microtiming. In practice, the pervasive presence of microtiming in all human performance must be understood not as an optional category but as a fundamental and unavoidable condition of musical time. It permeates every performance, even those striving for the most regular equality. As a consequence, the realized striation of any performance is only ever an approximation, because at the level of perception and execution no grid is perfectly realized. Even a percussionist articulating evenly spaced pulses at a meso timescale will inevitably introduce microtimings, destabilizing the very possibility of pure striation.

Interplay of Smooth and Striated Time

As all of these examples demonstrate, the richest musical effects arise when smooth and striated temporal organisations coexist and interact along a continuum. Rhythmic irregularity in *Blueshift*, the superposed tempi of polytempo textures, the internal counting of implicit striation, and the nuanced displacements of microtiming each place musical materials at different points on the same axis and at different timescales. Philosopher Gilles Deleuze and psychoanalyst Félix Guattari describe this interplay in *A Thousand Plateaus* not as a binary opposition but as a dynamic relationship: "What interests us in operations of striation and smoothing are precisely the passages or combinations: how the forces at work within space continually striate it, and how in the course of its striation it develops other forces and emits new smooth spaces" (Deleuze & Guattari, 1987, p. 500). Brian Hulse echoes this view, likening it to Wyschnegradsky's dialectic: "[S]mooth space is constantly being overcoded and stratified, while striated space is continuously broken apart by the flows of an anarchic nature" (Hulse, 2016, p. 282).

As a performing composer, my engagement with the interplay between smooth and striated time is less oppositional than exploratory. I seek to examine what each modality contributes to musical expression: how both regular and irregular structures can provide clarity, coordination, and tension, while at the same time allowing for openings in which performers can exercise interpretive agency and create moments of temporal freedom. My compositional practice is therefore oriented toward renegotiating thinking in oppositions, treating them not as antagonistic but as complementary forces whose interaction generates expressive depth.

Quantifying Speed

While smooth and striated temporalities are established within musical discourse, the distinction between them becomes especially pronounced when attempting to quantify speed. In physics, velocity is defined as the change in distance over time. A musical equivalent might be tempo, typically measured in beats per minute, or further refined through subdivisions such as tuplets to estimate note-level activity. This kind of quantification is appropriate in striated time, where events are distributed at regular intervals and measurable durations correlate with perceived speed. However, this formula is one-dimensional, leaving out the relationships between different musical layers, as well as the interaction of distinct timescales.

Measurements of durations are far less meaningful in the context of smooth time where rubato, fermatas, grace notes, heterophony or indeterminacy introduce temporal variability shaped by human interpretation. In these cases, the timing of events is unpredictable and often non-metric, making measurements incompatible with the lived musical experience. As a result, smooth time can only be described in terms of statistical density, the number of perceptual events within a span, without capturing their expressive or perceptual effect.

Crucially, density alone, whether expressed as a tempo indication or as a tally of irregular events, does not yield a consistent impression of speed. Identical tempi can produce vastly different temporal experiences, as is evident in everyday listening, where the same notated tempo can feel radically different across different pieces. Differences in rhythmic subdivision, articulation, harmonic rhythm, dynamic shaping, and timbral attack can redistribute where events feel concentrated or sparse, yielding substantially different impressions of speed. Likewise, counted events across longer spans may be perceived in markedly different ways, depending on their distribution, articulation, and interaction with other musical parameters. The way musical parameters – pitch, harmony, rhythm, phrasing, dynamics, timbre, and texture – are implemented across different timescales decisively shapes the larger temporal framework. Just as clock time fails to capture the richness of lived duration, numerical density lacks the nuance required to convey musical temporality. Within striated frameworks, where regularity prevails, density becomes more interpretable, perceived qualitatively as fast, slow, or moderate. Even though such measurements of striated density are limited since they fail to take into account layering in music, they nevertheless remain meaningful indicators of perceived speed. This is evident in the long-standing practice of tempo markings and the Italian terminology for tempi, which, while approximate, continue to provide effective guidance for performers and listeners. In this way, any temporal span containing internal regularity may be described in expressive terms, whereas smooth passages resist such codification.

Other Types of Musical Time

The smooth and striated classification, while conceptually useful, is not without its limitations. Grisey criticized Boulez's temporal model for being "arbitrary and generally dualistic," arguing that it oversimplifies the complexity of temporal perception and musical structure (Grisey, 1987, p. 239). In his essay "Tempus ex Machina: A Composer's Reflections on Musical Time," Grisey reframes the same underlying spectrum in terms of order and chaos and proposes an expanded typology that maps musical time across five gradations, each defined by its level of temporal predictability. In this sense, his intervention does not abandon the idea of a continuum between poles, but cautions against treating the two terms as exhaustive categories. This broader framework retains the clarity of a two pole continuum while offering finer distinctions that account for dynamic and indeterminate temporalities.

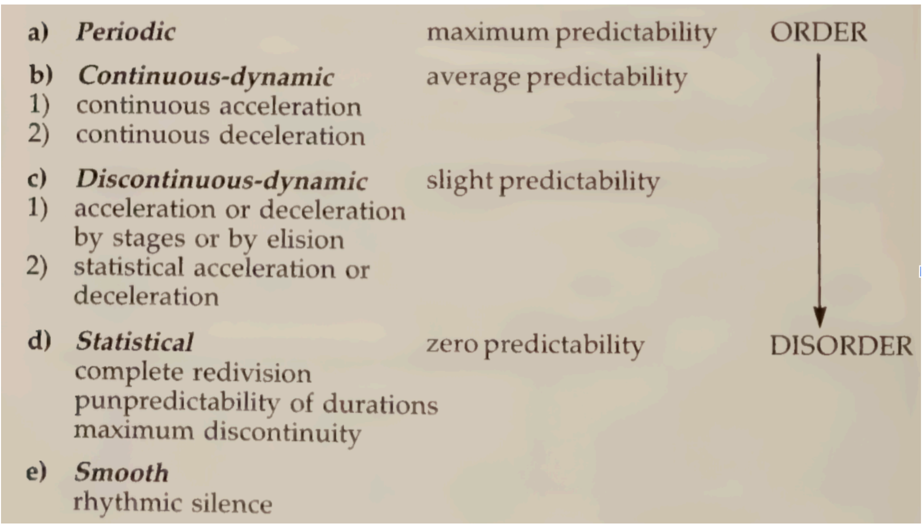


Figure 2.1, Temporal categories from *Tempus ex machina* (Grisey, 1987, p. 244).

- *a) Periodic time* corresponds closely to what Boulez terms striated time. It is characterized by regular pulses or subdivisions, metric structures that form the backbone of most Western musical notation.

- *b) Continuous-dynamic time* involves gradually shifting speeds that remain internally consistent, such as a smooth accelerando or ritardando between two defined tempi.

- *c) Discontinuous-dynamic time* encompasses irregular temporal structures shaped by rubato, fermatas, indeterminate durations or complex tempo modulations. This category aligns with many practices associated with smooth time, as it depends heavily on performer interpretation and does not conform to regular pacing.

- *d) Statistical time* reflects a significant departure from traditional models. It refers to temporal distributions shaped by stochastic processes, chance operations or probabilistic densities as exemplified in some works of Xenakis, such as *Metastaseis* (1953–54) and *Pithoprakta* (1955–56).

- *e) Smooth time*, in Grisey's specific usage, refers to the absence of rhythm altogether: a state of rhythmic suspension characterized by silence or long sustained tones. It represents a zone beyond discernible events, where time is not segmented but felt as static or continuous.

The inclusion of statistical time is significant. Rather than positioning it as an alternative to Boulez's smooth and striated model, it can be understood as one of Grisey's most consequential refinements of that continuum. Statistical time introduces an organizational logic in which temporal patterning is not primarily anchored in metrical regularity or in the intentional shaping of durations by performers. Instead, time emerges through probability fields, densities, and distributions. This still sustains a sense of gradation between order and chaos, but it does so without relying on the beat based regularities that enable conventional parsing.

Grisey's framework can therefore be read as an expansion of Boulez rather than a repudiation. By naming intermediate regimes, including continuous dynamic and discontinuous dynamic time, it shows how predictability and temporal control can be composed as a matter of degree. It also makes explicit how texture, density, and varying degrees of control or indeterminacy contribute to temporal experience. Grisey's typology thus points toward a wider field of temporal models that complicate both binary and hierarchical accounts of musical time. Time need not be reduced to a fixed metric or fluid continuum. It can be approached through multiple organizational logics, each tied to specific compositional or performative contexts.

In his essay "Action Time," composer, theorist and poet Samuel Vriezen extends this perspective by identifying multiple modalities of musical time, including *phrase time*, *clock time*, *divine time*, *action time*, *network time*, and *page time* (Vriezen, 2012, p. 5). Each modality foregrounds a different variable through which musical temporality is structured, whether by phrasing, duration, divine alignment,[18] performative decisions, interdependent systems or spatial notations. In analyzing Cage's *Number Pieces*, Vriezen focuses on the tension of *clock time* (objective, measured durations) and *action time* (performer-determined within those durations): "This combination of time types gives the *Number Pieces* their highly mysterious quality, which is one of blurring time itself" (Vriezen, 2012, p. 9). Such multiplicity complicates any attempt to define musical time in singular terms. Instead, it reveals temporality as a layered and relational phenomenon emerging from the interaction of structure, interpretation, and the conditions of performance.

My composition *Plutoid* explores the intersection of *action time* and what Vriezen refers to as *network time* - defined as "the network of combinations and possibilities of actions that depend on each other, generating a particular quality of performer interaction" (Vriezen, 2012, p. 7). The piece is constructed around interdependent gestures that form a flexible web of timing relationships among performers. One of its

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[18] Divine time can be defined as a non-chronological, non-metric temporality attributed to a deity, in which all moments are held in an undivided present and whose interventions appear within human, linear time without being bound by its succession or duration.

central techniques, which I call the "repeat button," involves Player 2 repeating an improvised phrase when Player 1 triggers the reset with a short cue. This interaction introduces an action-based, non-metric temporality, in which time unfolds through local decision-making rather than a fixed structure.

The temporal identity of Player 2's phrase is variable - it may fall anywhere along the smooth–striated continuum - but the interruptions by Player 1 inject an additional layer of smooth, performer-driven time. Later in the piece, explicitly striated materials such as scalar passages and accelerated hockets are introduced, only to be abruptly disrupted by similar performer-controlled cues.

Plutoid (2008)
for five players
Ned McGowan

1 plays cue
2 repeats a phrase
1 restarts 2 with same cue

3 plays cue
4 repeats a phrase
3 restarts 4 with same cue

2 plays cue, 1 + 3 improvise wild stuff
2 plays cue, 5 plays long note
repeat

4 plays phrase (6 seconds)
1 plays 1 beat phrase
2 plays 1 beat phrase

5 improvises text/ musical material
3 starts 5 over (with new text/material)

1 plays cue
3 repeats a phrase
1 restarts 3 with same cue

4 plays cue to switch between each following step

1 and 3 alternate notes with gradual accel.
2 and 5 play long loud notes
1 plays ascending scale, started over by 2
1, 2, 3 and 5 – wild improv.
Silence
1, 2, 3 and 5 – wild improv.
1 and 3 alternate notes with gradual accel.
2 and 5 play long loud notes
1 plays ascending scale, started over by 2

3 cues
5 improvises text or musical material
3 starts 5 over (with new text/material)

4 plays phrase (6 seconds)

4 plays cue
1, 2, 3 and 5 – wild improv.

4 plays cue
Silence

Example 2.52. *Plutoid*, score excerpt. Video.

In the final section, a regular pulse governs the entrance of short samples by five players, but each sample unfolds according to its own temporal logic - ranging from tightly metrical to fluid and unmeasured - depending on the musical material created by the performers.

1 2 3 4 5	5 4 3 2 1	2	3 3 3 3
1 2 3 4 5	5 4 3 2 1	X X	4 4 4
1 2 3 4 5	X	2 2	5 5
5 2 3 5 4	5	X X	
5 3 2 5 4	X	2 2 2	5 times: 5 5 4
1 2 3 4 5	5 4 3 2 1	X X	(1 2 3 4 5)
1 2 3 4 5	X X	1 2 3 4 5	
3	1 2 3	X 5 X 4 X	X 1 X 1 X X
1 2 3 4 5	X X	3 X 2 X X	1
3 3	2 4 5	1 2 3	X X X X
1 3 2 4 5	X X	4 4 4 4	1 1
2	1 1	1 2	X X X X X
1 3 2 5 4	1 2 3 4 5	5 5 5 5 5	
2 2 2	X X	3 3 3	8 times – 1 X
1 2 3 2 1	2	2 2	(1 2 3 4 5 6 7 8)
X	X X	4 4 4	
4 4	3 4	1	1 2 3 4 5
1 2 3 2 1	X	5 5 5 5 5	
5 5 5	5 5	1 1 1 1 1 1	
X	X X	2 2 2 2 2	

Example 2.53. *Plutoid*, score excerpt. Video.

Plutoid thus exemplifies how contrasting temporal modes can coexist and interact within a single compositional framework. Rather than functioning as static categories, these temporalities emerge through the interplay of real-time decision-making, relational gestures, and inter-performer responsiveness. Time in the piece is not imposed from above but arises from within the musical and social dynamics of the performance itself.

Recognizing the coexistence of multiple types of musical time reveals how elusive and expansive the concept of time in music actually is. Temporal perception and structure are shaped by virtually every musical parameter. Rather than viewing time through a discrete set of fixed categories, it is more accurate to understand it as a continuously evolving field, formed through the interaction of many variables, whether they operate on small or large timescales, and whether their role is primarily expressive or structural. Even a composition based on a single gesture can embody a wide range of temporal nuances, depending on how that gesture is shaped through breathing, phrasing, intonation, dynamics, or timbral shifts. Each of these musical dimensions can function as a generator of temporal experience, so that time in music appears less as a preexisting container and more as an emergent property of musical articulation.

Broad categories such as metric time, phrase time, clock time, or phase time[19] may be identified, as I explore in more detail in Chapter 4 on polytempo, but these are only partial lenses. The temporal character of a musical work often emerges from the interplay between these modalities. Cage's "Number Pieces" explicitly juxtapose different temporal types: fixed clock time frames coexist with performer led action time, while the articulation of individual notes through micro dynamics, phrasing, and tone colour generates yet another temporal layer. This multiplicity does not undermine the possibility of analysis. Instead, it demands attentiveness to the layered and interdependent ways in which time is constructed and perceived.

[19] Phase time is explored in more detail in Chapter 4.

It also complicates any straightforward account of musical speed, since speed is always enacted within and across these overlapping temporal regimes.

Despite this multiplicity, it remains possible, and in my view analytically useful, to map musical time along a continuum between the smooth and the striated. Pierre Boulez's formulation provides the basic two term frame used throughout this dissertation, because it foregrounds how temporal experience can oscillate between continuous flux and metrically articulated segmentation. Gérard Grisey's approach is not rejected here, nor is it posed as a competing model. Instead, it expands Boulez's continuum by reframing its poles as order and chaos and by articulating gradations between them, including statistical time. This expansion is particularly valuable for an inquiry into speed, because it clarifies how changes in density, predictability, and perceptual thresholds can move a passage along the continuum and thereby reshape perceived speed. Music organized around action aligns closely with the smooth end of this spectrum, where timing is flexible and flow is relatively indeterminate. Music that relies on statistical densities can blur the boundary between smooth and striated time by combining indeterminacy with perceptible rhythmic detail. At the more striated pole, temporal regularity serves highly functional purposes, particularly in ensemble coordination, anticipation, and the establishment of groove. Yet striation is not only practical. Its regularity enables expressive musical logics, including the rhythmic shaping of phrasing, the construction of formal proportions, and the cultivation of tension and release. It also supports the creation of potentially large scale structures through the use of rhythmic tools such as tempo, tuplets, metre, and rhythm.

At the meso level timescale at which patterns, beats, and gestures interact, a striated conception of time still plays a dominant role in much Western classical and contemporary music, and in many nonclassical styles such as pop and jazz. At the same time, recognizing the coexistence of multiple temporal types makes clear that striation is never the whole story. Smooth time is always present in some form or timescale.

For the specific purposes of this investigation into speed, the continuum between smooth and striated temporalities therefore offers a productive simplification. It does not replace the complexity of multiple temporal types, but instead cuts across them and highlights how different musical constructions afford or resist control over perceived speed. The more a passage relies on stable, shared temporal reference points, the more tightly it constrains speed; the more it suspends or disperses these reference points, the more fluid its sense of speed becomes. These qualities are readily audible in all music.

In sum, this section has argued that musical time is layered, relational, and often internally contradictory. By situating moments at various timescales along a continuum between smooth and striated temporalities, it becomes possible to gain analytical traction on that complexity. Even when a passage resists straightforward classification, placing it on this spectrum can clarify how time behaves, how it is perceived, and how it contributes to the expressive identity of musical speed that is central to the rest of this dissertation.

2.5 Listener-Environment-Musical Stimulus-Interaction Model and Situated Knowledge

> *You do not know beforehand what a body or a mind can do, in a given encounter, a given arrangement, a given combination.* (Deleuze, 1992, p. 627)

> *You don't perceive objects as they are. You perceive them as you are.* (Eagleman, 2015, p. 32)

To understand the role of speed in music, it is essential to consider not only compositional strategies and performance techniques, but also the broader conditions under which music is created, experienced, and interpreted. I therefore draw on the LEMI model proposed by music psychologist Michelle Phillips in *Music and Time* (2022), which foregrounds the interplay of listener, environment, and musical stimulus. Read through Donna Haraway's theory of situated knowledge, developed in her essay "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective" (1988), I treat these interacting agents - listener, environment, and musical stimulus (including performers and instruments) - within a single musical event rather than as independent domains; they are analytically separable, yet co-constitute dimensions that mutually condition how speed is articulated and perceived. Musical speed is not a fixed attribute but an emergent quality arising in relations between composer and performer, performer and instrument, instrument and acoustics, acoustics and environment, and listener and space. My situated knowledge is that of a classically trained flutist, composer, and improviser, shaped by work with virtuoso tempi and rhythmic complexity, slow Indian melodic practice, systematic metronome training, and the pedagogy of "Advanced Rhythm and Pulse."[20] These experiences have shaped both the speeds I can enact as a performer and the temporal constructions I write for others. In the following subchapter, I use the LEMI model, informed by Haraway's philosophy, to show how experiences and articulations of speed depend on shifting constellations of embodied, environmental, cognitive, affective, and material conditions, and how such situated capacities inform concrete compositional and performative choices.

Listener

The first facet of the LEMI model concerns the personal characteristics of the listener, such as age and musical experience. A child with little exposure to classical music might perceive a fast tempo as chaotic or overwhelming, while an experienced adult musician may interpret the same tempo as energetic and exhilarating. Similarly, an elderly listener might prefer slower pieces due to personal aesthetic preferences developed over time. Although I take the audience into account when composing, it remains impossible for creators of music (composers, performers, organizers) to fully predict how listeners will perceive the speed of a piece. Individual circumstances inevitably shape their musical experience. Additionally, from the perspective of situated knowledge, which holds that all knowledge is produced from a specific position and perspective rather than from an objective, universal standpoint, the listener must be understood not as a general category but as a historically and materially grounded subject (Haraway, 1988, pp. 581-583). A listener's perception is shaped not only by biological or experiential factors but also by cultural background, socioeconomic positioning, gender, race, and technological literacy.

Much of my work is written for a broadly educated Western-European audience accustomed to classical and contemporary idioms, yet I have also often performed my music in Indian contexts where expectations about phrasing, timing, form, and decorum are very different. While taking these different constellations into account, I am aware that the ages, backgrounds, and listening habits of individuals at any given performance will filter my choices in ways I can only partially anticipate. Rather than aiming to generalize

[20] "Advanced Rhythm and Pulse" is a practice-driven course that develops embodied rhythmic precision and feel, provides tools for analyzing diverse rhythmic systems, and supports application in contemporary classical, jazz, and Indian performance practices.

across listeners, reframing the LEMI model through situated knowledge emphasizes how specific listening positions and identities shape the perception of speed.

When I compose, I am also a listener to the music. The speeds I choose are shaped not only by my embodied experience as a performer but also by decades of attentive listening across a wide range of musical styles and traditions. I have engaged deeply with Indian classical music and its rhythmical structures;[21] with jazz and its groove-based timing; and with electronic music that manipulates pulse and density in unfamiliar ways. These listening experiences have formed cognitive and affective frameworks through which I recognize patterns, anticipate change, and evaluate musical tension and resolution.[22] They are just as decisive as my physical training when I make compositional decisions.

Environment

Physical spaces influence how fast music is performed because their acoustical characteristics affect how sounds resonate. The size of the hall and whether the performance takes place indoors or outdoors play crucial roles. Considerations of musical detail and reverberation directly influence performance choices. Audio engineer Barry Blesser and scholar Linda-Ruth Salter make this point vividly when they state: "At a minimum, for example, tempo and reverberation must be matched; a rapid tempo in a cathedral produces musical soup" (Blesser & Salter, 2007, p. 128). This illustrates how reverberant environments such as cathedrals necessitate slower tempi in order to maintain clarity, while drier acoustics support more subtle sound onsets, faster tempi, and stronger rhythms.

Although Italian tempo indications can be loosely associated with numerical beats per minute, the final tempo in a performance or recording often shifts according to the acoustical environment. Steven Schick summarizes this phenomenon in *The Percussionist's Art*, observing that "every percussionist who has played a large tam-tam or a piccolo wood block knows that tempo and sound are intimately linked: resonant sounds need time to bloom and decay and tend towards slower tempi while secco sounds disappear quickly and prompt the player to move ahead more quickly" (Schick, 2006, p. 190).

Another way to address these acoustical effects in performance is through microtiming rather than through changes in the overall tempo. Instead of adjusting the basic pulse, a performer can allow certain notes a little more time to resonate, creating a small shift in the temporal grid while keeping the tempo intact. An example of this effect can be found in section 4.2 The Rhythmic Grid, which discusses microtiming. This approach can be especially useful in pieces that include fixed media parts, where the speed is predetermined and cannot be altered during performance.[23] In such contexts, microtiming offers a way to respond to the acoustics of the space and to maintain musical coherence between the performed part and the fixed media layer, while preserving the proportional speed relationships that are central to the work's design.

Haraway's notion of situated knowledge, which emphasizes that perspectives and knowledge are irreducibly contextual rather than universally objective, resonates with Christopher Small's proposition in *Musicking* (1998) that musical meaning arises through the act of musicking itself, understood as an embodied and social practice embedded in particular relationships and settings. Together, these perspectives suggest that environments are not passive, neutral containers in which music simply unfolds,

[21] See *Cycle Games 1*
[22] The cognitive and embodied aspects of listening are treated in depth in the section Density and Motion.
[23] Fixed media parts since the advent of digital audio have often consisted of sound files that are triggered by, or in response to, the timing of the live performer. I explored this in *For Bob*, in the version for the MIDI controlled Fokker organ, where I created a system to trigger changes in the fixed polytempo textures according to my phrasing at the time of performance, instead of being resigned to follow a single, unyielding temporal layer.

but active participants in the construction of a performance. Moreover, a venue carries with it not only acoustic properties but also layers of historical association, institutional frameworks, patterns of access, social expectations, and aesthetic hierarchies that shape how listeners orient themselves toward the music and how parameters such as tempo and density are perceived. A living room and a concert hall are not only acoustically distinct but also culturally and politically differentiated: the former may invite casual, intimate engagement, whereas the latter tends to impose codes of decorum and attentiveness. Each of these situated configurations contributes to how music is made, how it is heard and how it is understood.

These theoretical considerations return in a concrete way in my own performances, where I am continually reminded that I do not occupy a neutral vantage point but a specific position within a particular setting. In recent years I have played my music in various European contexts, including a community church, a conservatory, a large concert hall, a nursing home, and the open space of beach dunes, as well as in a Hindu temple in India, a private hall in rural Japan, and a downtown Tokyo venue. Each of these sites brings not only a different acoustic but also a different tempo of beginning. In European classical venues, a charged silence and the ritualized entrance applause tend to lead almost immediately to the first sounds. In the Hindu temple, performances often open with an extended speech and a drawn-out tuning before the music proper begins. In the nursing home, a short conversation or interactive introduction may precede any formal start. In each case I adjust repertoire, overall tempo, gestural speed, and microtiming in response to the expectations and attentional focus of those present, and I do so with an awareness that my own background and role as European composer–performer are part of what is being negotiated. Such situational adaptation underscores that decisions about speed are inseparable from the environments, cultural conditions, and positionalities in which the music is made and heard. At the same time, these environments are always also encountered through the listener's shifting emotional state.

Mood of the Listener

Although the listener is treated as an independent agent in the LEMI model, LEMI nonetheless considers the listener's mood as an environmental factor: one of the local conditions that frames listening in the moment and shapes the perception of musical time. This mood-related modulation of perception is distinctly of the present moment; unlike inherent characteristics or long-term training, it operates within the immediate moment of listening and is responsive to transient internal and external states. When someone is anxious or agitated they may perceive a musical passage as dragging or excessively slow, while the same passage might feel swift and light to the same person when feeling content and relaxed. This phenomenon can be more deeply understood through the lens of attentional orientation - the idea that attention is not a passive process but one guided by emotional, cognitive, and contextual signals (Gross, 1998; Chatterjee, 2013). Broader theoretical frameworks such as the *biased competition model*, a neural theory of selective attention proposing that competing stimuli are prioritized based on relevance and emotional salience (Desimone & Duncan, 1995), and *affective chronometry*, which examines the timing and duration of emotional responses (Davidson, 2015), further support the view that the emotional context shapes perceptual prioritization over time. I have noticed how my own emotional state while listening to a premiere performance of one of my own works - particularly heightened anticipation or excitement - can alter my perception of tempo. What seems too slow onstage often feels more balanced when I revisit the performance in a calmer setting via a recording. This personal observation illustrates how emotional context and attentional orientation work in tandem to modulate the felt experience of musical time.

According to Haraway, emotional states are not ahistorical or simply interior phenomena; they are situated and emerge within specific configurations of social relations, institutional settings, cultural histories, and material circumstances. The affective dimension of listening arises from one's embeddedness in broader social, political, cultural, and historically situated temporal conventions and expectations. As sound studies scholar Marie Thompson observes: "The dividing line that separates the tolerated from the taboo and the permissible from the unacceptable varies between as well as across cultures" (Thompson, 2021, p. 21). For instance, the anxiety that accompanies listening during a high-stakes premiere may be not only personal, but also structured by institutional pressures, performance expectations, and prior cultural experience with particular genres and forms. More broadly, Haraway's and Thompson's accounts of situated affect and culturally variable sonic norms show that listening is framed by anticipatory structures: what a listener expects to unfold, when change is likely to occur, and how long a musical idea should persist before it transforms. Mood does not generate these expectations; like other specificities of a listener in a particular situation, it modulates how they are perceived, including how strongly delays, accelerations, or ruptures are felt. From this perspective, mood is not just a random or private variable but a socially and materially constructed filter that mediates musical time, informed, for example, by aesthetic templates and enculturated habits of attention.

Musical Stimulus

In LEMI, the third analytic category is the Musical Stimulus, understood as the manner in which musical ideas are presented and unfold in time. It includes both compositional design and performative realization, which may be undertaken by the same person, and it is further mediated by the instrument, the voice, or a computer algorithm through which the material is realized (Phillips, 2022, p. 13). In relation to speed, the composer can shape musical time through technical devices such as rhythm, meter, and tempo, as well as through the ways musical material is developed and transformed over time. In relation to speed, the composer can shape musical time through technical devices such as rhythm, meter, and tempo, as well as through the ways musical material is developed and transformed over time. While the tools of temporal organization serve the proportional realization of musical development, the process of unfolding material is typically addressed in discussions of form, also known as the macro timescale. These include structural elements such as motivic development, phrase architecture, repetition and variation, contrast, and sectional articulation. In my exploration of speed in music, the primary concern lies not with formal schemes as such, but with the specific temporal devices that shape musical flow, that is, in the meso timescale. This includes detailed examination of tuplets and polytempo, as well as the broader exploratory perspectives articulated throughout Chapter 2, such as thresholds of perception, temporal resolution, density and motion, and smooth and striated time. Within this meso level, notation becomes a primary interface between compositional intention and performed speed.

Initially, the manner in which a composer notates the music in the score greatly informs the performer's approach. Composers influence speed not only through rhythm, meter, and tempo, but also through articulation, dynamics, phrasing, ornamentation, timbre, instrument-specific techniques, spatial notation, text instructions, graphic symbols, register usage, and notational density. For example, a Western score is therefore not a neutral container. It encodes particular aesthetic and institutionalized ideas about clarity, hierarchy, and legibility, and it is entangled with the material affordances of instruments and digital tools that enable or restrict particular gestures, tempi and textures. To situate music is to recognize these social, material, and historical conditions, which shape what forms of music become possible, legible or desirable in a given context. Musicologist Nicholas Cook takes this a step further with his statement that "notations are anything but transparent or neutral: they are agents in processes of musical change" (Cook, 2022, p. xv). Cook argues that notation actively shapes musical practice, because notation and notation-based analysis form a recurring circle that privileges certain ways of making and hearing sound. Those privileged modes then feed back into how notation itself is conditioned, so that notation becomes an agent of musical change rather than a passive record.

In my own practice as a European composer, performer, and improviser in the early twenty-first century, these conditions are very concrete. My work draws on Western classical, experimental, and groove-based traditions, on digital technologies, on institutional frameworks for new music, and on intercultural collaborations. These contexts shape how I conceptualize and enact musical speed and which questions I consider musically meaningful. Western staff notation allows me to communicate efficiently with performers trained in the same traditions, yet it often proves inadequate for expressing temporal flexibility and microtiming, especially in pieces shaped by oral or improvisational settings.

Whereas the LEMI model and the concept of situatedness imply a gap between compositional intention and performed outcome, my work often begins from inside performance, by which I mean that compositional ideas are first tested against the embodied realities of playing before they are stabilized through notation. For example, when I sketch fast material for flute, I physically try fingerings at extreme tempi to feel where articulation begins to blur; when writing for trumpet or saxophone, I consider embouchure resistance, tonguing patterns, and the fatigue profile of repeated attacks; at the piano, I experiment with hand redistribution and pedaling; in percussion writing, I assess stick rebound, damping time, and the spatial choreography required to move between instruments at speed. In each case, speed is not treated as an abstract metronomic value but as a threshold emerging from gesture, coordination, and instrument-specific affordances. This approach does not assume that my body is normative, but it uses embodied trial as an initial diagnostic tool for what kinds of temporal densities are viable, idiomatic, or deliberately resistant. Grounding decisions in direct performative testing foregrounds the contingencies of technique, stamina, and acoustics in a particularly explicit way. I try to narrow that gap by embedding performative logic into the score through notational choices that are informed by my embodied expertise, developed to a specialist level, in speed, rhythmic complexity, and coordination. Inevitably, I use my own playability as a first proxy for what might be feasible for other highly trained performers within comparable performance traditions. This proxy is limited though, and it serves a different purpose from the testing described above. Trying material on my own instrument helps me predict how speed will color timbre and gesture, but it does not establish what will be fluent for other performers, other bodies, or other instrumental techniques. What feels efficient with my training and physical habits may be awkward, inefficient, or disproportionately difficult for another performer, and it does not automatically generalize across instruments. For this reason, I treat playability as a hypothesis to be tested in rehearsal and refined through dialogue, notational adjustment, and, when necessary, revision of the musical material. In practice, this process foregrounds the performer's interpretive agency, because decisions made in rehearsal do not merely realize the score but actively participate in shaping what the piece becomes.

Collaborations with Indian musicians have challenged the assumptions built into my notational practices, and they bring the topic of intercultural expression into contact with the performative assumptions encoded in Western notational standards. The use of tuplets in my scores, for instance, is often influenced by rhythmic structures that are intuitively felt and transmitted orally in South-Indian music. But I have come to see that the tuplets as I notate them are not neutral transcriptions; they reflect a present-day Western logic that seeks to rationalize and measure rather than to embody or internalize rhythm. Western notation tends to relate rhythmic values to a beat subdivided into four or eight equal parts, whereas South-Indian rhythmic thinking often organizes time through additive groupings, internal accents, and cyclic relationships that produce their own metrical identities often significantly distinct from the pulse. In the following passage from *Concerto for Indian Percussion* (2022), the entire ensemble accentuates groups of seven 16ths in a 7/4 metered bar and I have chosen two different approaches to notate them. For the winds and percussion, which are filled with 16th and 32nd notes, the beaming follows the seven 16ths grouping (4+3), in order to bring out the rhythmical groupings. The string parts, with short notes and rests, place accents syncopated to standard beats of four 16ths, which are considerably easier for a section to coordinate than larger groups of seven 16ths.

Example 2.54. *Concerto for Indian Percussion*, score excerpt. [Audio example.]()

Normally, notating opposing rhythmic structures within ensemble parts can significantly challenge synchronization between the players, particularly in conducted pieces. In this un-conducted work, written for highly experienced musicians, this discrepancy did not pose a problem. Explorations like these demonstrate how notation can both reveal and conceal rhythmic understanding, and how notation can open new ways of bridging divergent rhythmic systems. In Cook's terms, notation is "anything but transparent or neutral" and can function as an agent in processes of musical change (Cook, 2022, p. xv). Here, the notational decisions do not merely represent a seven-note grouping; they prescribe how performers should parse, count, and coordinate it in rehearsal. Repeated over time, such prescriptions can sediment into ensemble technique and subtly reshape habitual timing and perceived speed.

Such encounters have forced me to reconsider how rhythmic structure is conceptualized and communicated, and to search for approaches that allow for more permeability between metric clarity and embodied flexibility. Often I notate rhythmically experimental passages three or four times before settling on the published version. In the above example, the winds could have been beamed according to the beat, using accents to mark the beginning of each group of seven notes.

Example 2.55. *Concerto for Indian Percussion*, score excerpt.

While certainly not impossible to play, this version does not reflect the phrasing of the material, the natural agogics that emerge from groups of seven notes. Vice versa, the strings could have been notated according to the grouping:

Example 2.56. *Concerto for Indian Percussion*, score excerpt.

This may not be difficult for a string player used to playing odd-meter dances (such as in Balkan folk music), but that is not necessarily the standard for classically trained players. Any approximation of the rests in this passage would derail the lining up of both layers. Since the phrases of seven 16ths in the winds are all occupied by notes, their part is more straightforward to execute, and thus maintain the agogics of septuplets. This observation is hardly new: from Bartók's early attempts to render Eastern European folk repertoires on the staff to later ethnomusicological work by Simha Arom, Kofi Agawu, and Gerd Grupe, scholars have repeatedly pointed out that Western staff notation tends to impose its own metric and pitch hierarchies on orally transmitted practices and can therefore only partially represent their rhythmic and timbral nuance (Arom, 1991, p. 226-228; Agawu, 2003, p. 246; Grupe, 2005, p. 87-103). My discussion here aligns with that body of work but approaches it from the vantage point of a composer and performer who must decide, in concrete cases such as *Concerto for Indian Percussion*, which notational compromises to accept and how those choices will affect performers' experience of speed and ensemble coordination. Understanding music as situated has helped me to reframe my role, not as an ostensibly detached, neutral organizer of sound, as if musical decisions could be made from outside the material and social conditions that make them possible, but as someone working within historically saturated tools and practices that require ongoing negotiation, critical awareness, and collaboration. In this sense, every compositional decision about speed involves a reckoning with the material and cultural infrastructures that inform what can be written, heard, and shared.

Alongside these notational questions, digital tools add another layer of conditioning. The grid-based design of most sequencing and notation software encourages regular subdivision and metric stability and tends to quantize the layered, elastic temporalities I wish to explore. These software environments extend Cook's argument that notation is not neutral but acts as an agent in processes of musical change into the digital sphere: their default grids, quantization schemes and tempo maps function as notational agents that channel compositional experiments toward particular, often regularized, temporal norms. A computer can generate almost any speed, which makes it a powerful exploratory partner, but it treats time as programmable parameters such as tempo, grid resolution, and quantization. Material that sounds convincing in the studio may not contain enough information for clear speed indications when played by human performers. It is not mediated by instrumental technique or physical gesture, nor realized in a specific acoustic space. This disjunction has led me to search for notational and technological solutions that support greater temporal nuance and better account for the perceptual and physical realities of performance. I have experimented with rhythmic tools and alternative notations, and with the live use of metronomes, to explore how internal and external timekeeping systems can interact, collide or destabilize one another in performance.

One way I address these tensions is by shaping compositional decisions around the anticipated interaction between performer and score, especially in relation to the performer's training and background (for example, Western classical, jazz or Indian music). The conditions under which material is produced and realized in performance, whether through real-time decision making or the execution of a notated part, have a strong bearing on how speed is shaped. For classically trained musicians with limited experience or comfort with improvisational approaches, I often construct situations in which specific parameters such as timing, speed, number of repeats or the creation of short cells may be decided in the moment, while others such as pitch collections, rhythmic frames or larger formal cues remain fixed. I design these frameworks not simply to add variability, but to amplify the individual expressions of the performers, foregrounding their own perspectives, decisions, and embodied knowledges as constitutive of the music. These settings invite performers into improvisational modes of attention and response without requiring them to abandon notational security. My own performative experience with improvisational behaviors has been crucial in revealing the kinds of expression that such behaviors afford, and I consciously encode these possibilities into my compositional choices. The pieces presented in this dissertation, such as *Plutoid*, *Tools*, *Torrent*, and *Cycle Games I*, exemplify different configurations of this distribution of decisions and of the resulting treatments of speed.

Without attempting a general definition of improvisation, I align here with the broader perspective of Cobussen's (2017) description of improvisation as a dynamic field in which performers, instruments, spaces, and sounds continuously interact. The variability described above, and emphasized in the LEMI model, can be understood as a spectrum of more or less spontaneous decision making, including choices about speed, density, and articulation. Each musical realization unfolds through a mesh of embodied decisions and context-specific negotiations between performer, material, and environment. This responsiveness is not an additional layer that simply accompanies performance. It is part of what it means to perform, whether in a fully notated context or in situations where players are asked to invent material. From this perspective, the perception and enactment of speed emerge from the interaction between planned structures and momentary adjustments rather than from a predetermined plan alone. Although a full theorization of improvisation lies beyond the scope of this dissertation, its implications for the expression and manipulation of speed remain central to the broader investigation, and a case study is given in Chapter 5.

Conceiving performance as an improvisatory field invites a broader view of how speed is perceived and embodied. Beyond the auditory dimension, visual and kinesthetic aspects of performance - gestures, movements, and spatial relations - play a decisive role in how listeners experience musical density and motion. This becomes especially evident in studies that show how visual embodiment can reshape our sense of musical time. A short note might feel longer when it is accompanied by an expansive physical gesture (Schutz & Lipscomb, 2007). This notion finds a parallel in pianist and artistic researcher Guy Livingston's dissertation on silence, in which he analyzes how pianists perform the opening rests of Beethoven's *Sonata Opus 111* (Livingston, 2025, pp. 123-150). According to Livingston, these rests - though unremarkable on the page - become dramatic and expressive moments through visual embodiment. Pianists such as Sviatoslav Richter, Katie Mahan, and Daniil Trifonov shape the perception of silence not only through timing and pedaling, but through highly stylized gestures, facial expressions, and bodily posture. These embodied silences vary greatly in their interpretative function: some are abrupt and interruptive, others are connective and flowing. Importantly, Livingston observes that these visual performances of silence can also exceed or even contradict the auditory experience, making silence something to be seen as well as heard. This reinforces the idea that perception of musical time, especially moments of pause or stillness, is not confined to the ear but is shaped by an integrated sensorium of aural, visual, spatial, and kinesthetic cues. Some fixed media works complicate this claim because they withdraw the performer's body from view and shift temporal inference onto sound alone, even when the sonic material invites the listener to imagine sources or images, as in the clock sounds that open Bernard Parmegiani's *Entre Temps*. In other words, musical time is always perceived from somewhere, by a body that is located and conditioned.

Haraway and Artistic Research

Although Haraway does not address music directly, her theoretical framework helps resist a purely formalist view by emphasizing that musical practices are always situated and value-laden. Notation systems, performance conventions, and technological mediations all carry assumptions, histories, and inclusions as well as exclusions. As Haraway observes, "Feminist objectivity means quite simply situated knowledges… Only partial perspective promises objective vision" (1988, p. 583). This seemingly paradoxical phrase suggests that objectivity arises not from detachment or universality but from acknowledging one's own position. It is through the specificity of perspective - through being situated in a particular body, culture, and practice - that knowledge becomes accountable and meaningful. This notion underscores that every musical practice - whether composing, performing, or listening - is embedded in specific material and cultural conditions that shape what can be heard, valued or even imagined.

This situatedness is not a limitation but a foundation for artistic research. Through awareness of the specific conditions of my own listening, performing, and composing, I can more clearly articulate the insights, perspectives, discoveries, and decisions that emerge from my work. Artistic research allows these personal and embodied understandings to be shared - not as universal truths, but as situated contributions to a broader discourse about music and temporality. As Borgdorff argues, artistic research is grounded in the artist's perspective and in a productivity of knowledge that is embedded, experiential, and contextually situated (2012, p. 50). In this light, the specificity of my position becomes a resource: it allows me to treat my embodied habits as a classically trained flutist and composer as material for contextualization and reflection, rather than as an invisible background. In the following section on interaction, I treat performances of my own works as sites where these situated perspectives, and the agencies identified in the LEMI model, become experimentally entangled.

Interaction

Phillips' LEMI model helps to frame the experience of speed in music as an emergent property of the dynamic interactions between listener, environment, and music, with none of these agents considered in isolation. Read through the lens of Haraway's situated knowledges and Borgdorff's account of artistic research, these interactions are not only performance contingencies but research conditions: each performance becomes an experiment in how specific bodies, scores, spaces, and histories co-produce the experience of speed. This understanding is crucial in practice. For example, while performing one of my own works in a small space with dry acoustics, I might have the impulse to highlight the unhurried unfolding of a slow melodic phrase, drawing attention to its temporal spaciousness and expressive stillness. A slower speed could be conveyed not only by reducing the overall tempo but also by shaping the musical phrasing through subtle variations in dynamics, microtiming, and understated physical gestures. These expressive details become particularly effective in an intimate space, where the proximity of the audience allows for nuanced shifts in timing, dynamics, and physical movements to be clearly perceived. The score is not a fixed representation of the piece but a prompt for the performer to shape the music in response to the performance context. It invites adaptation of tempo, microtiming, and expression to suit the acoustics, audience, and other local conditions, allowing musical time to be sensitively tailored to its environment.

Mostly my pieces have been written for particular performers and venues, with carefully calibrated tempi and densities for those conditions. When the same work is later taken up by a different ensemble or performed in a radically different acoustic, the original temporal design rarely transfers unchanged: tempi stretch or contract, articulation patterns are modified, and local balances are renegotiated so that the piece can function in its new constellation of space, bodies, and listening habits. In this sense, the piece is not a static entity but a dynamic one. Some parameters may remain relatively stable, while others shift, to a greater or lesser extent, in response to the performance context. This variability does not preclude composing with clear temporal intentions. On the contrary, awareness of these contingencies has led me to design scores that build in a degree of flexibility around speed - for example with unspecified tempi (*Torrent* and *Telescopic Ladder*), synchronizing phrasing to breath (*Building Music*) and interactive timing (*Plutoid*) - so that performers can adapt to their own bodies and environments while still engaging with the underlying temporal propositions of the piece.

Roland Barthes' seminal essay "The Death of the Author" (1977) offers a complementary yet radical perspective that deepens this inquiry. For Barthes, the mere existence of a text always undermines the authority of the author; meaning is no longer restricted to the intention of the one who wrote the text, but generated by the multiplicity of readings. Additionally, Barthes' vision of the text as a "tissue of quotations" - drawn from many voices and cultural origins - resonates powerfully with both the LEMI model and the artistic practice described here. When I compose or perform, I participate in an unfolding network of musical references, cultural histories, acoustic environments, performing bodies, and listening subjects. My own voice is one among these, both participating in and shaping this evolving constellation of relations. The act of *musicking* thus becomes less about asserting the singular authority of the composer and more about recognizing that the work itself is woven from multiple influences, references, and pre-existing cultural materials, including as well as excluding conditions for diverse interactions and interpretations.

This position has concrete implications for artistic research. If the work cannot be reduced to a stable object authored by a single subject, then the research process must likewise reflect this distributed nature. In this context, situated knowledge - as theorized by Haraway - reinforces the idea that all musical perception, creation, and interpretation is embedded in specific bodies, histories, tools, and environments. Although the research presented in this dissertation is grounded in my personal artistic practice, this practice is not an isolated or entirely self-contained phenomenon; it consists of and contributes to a multiplicity of existing practices and interactions. However, the new insights that emerge from it must be understood as situated within my experiences as a composer, performer, and listener. Another researcher, composer or performer, even when addressing the same research question within the same domain, would inevitably arrive at different solutions and articulations. These findings are therefore not universal claims, but contributions that reflect a specific musical and intellectual trajectory. Just as Barthes urges us to abandon the myth of the solitary Author-God, Haraway's theories encourage us to reject the illusion of the objective, detached researcher. Instead, both models invite an embrace of partiality, relationality, and embeddedness.

Building on the previous discussion, I have turned what might otherwise be an informal adjustment of tempi, articulation, and clarity from venue to venue into an explicit research procedure. I treat each premiere and subsequent performance as an experiment in how a given temporal design behaves under different conditions, noting where speeds need to be relaxed, where density can be increased, and where notational changes might help future performers. In this way, performances generate situated knowledge about speed that feeds back into both compositional decisions and theoretical reflection. Recordings, even when I am the performer or producer, encapsulate only one possible encounter with the work rather than a definitive version. After each first performance I usually undertake a single revision, evaluating how the piece operated within its specific constellation of performers, acoustics, audience, and context, and encoding intentions that can sustain multiple interpretations. Once this revision is complete, I regard the score as provisionally finished and acknowledge that its subsequent lives will unfold through situated acts of interpretation beyond my direct control.

Conclusion: Speed as situated interaction

The LEMI model, Barthes' critique, and Haraway's situated knowledge converge to frame musical speed not as a fixed property embedded within "the work itself", nor solely dictated by compositional tools, but as an emergent phenomenon arising from situated interactions. This convergence challenges conventional views of tempo (and thus speed) as a stable and measurable constant, promoting instead a contextually sensitive approach to artistic creation. Within this framework, artistic research into speed in music is understood less as the pursuit of definitive answers and more as an ongoing practice of attuning to the multiplicity of temporalities, perspectives, and situated agencies that co-create musical experiences.

Having developed a working definition of musical speed and mapped several conceptual frameworks through which it can be understood, I now shift from explanation to application. Chapters 3 through 5 focus on the compositional and performative tools through which speed is shaped, negotiated, and made audible in practice. Chapter 3 takes tuplet writing as a primary mechanism for organizing speed within subdivided time, showing how different subdivisions generate distinct felt characters and technical demands. Chapter 4 extends this into polytempo, where multiple concurrent temporalities must be constructed and maintained through rehearsal strategies, attentional techniques, and technological supports, and where the tension between mechanical regularity and human expressivity becomes aesthetically productive. Chapter 5 then turns from the sounding result to the conditions of its production, proposing speed of creation as a framework for understanding how decision making unfolds across improvisation and composition. Together, these chapters operationalize the relational account of speed developed in Chapter 2 by examining how specific musical devices and working methods produce, constrain, and transform experiences of speed.

Chapter 3: Tuplets

3.1 What is a tuplet?

In music practice and theory, and within this dissertation's broader investigation of speed, tuplets are a primary means of articulating time and subdivision. By examining tuplets, this chapter addresses the regulated dimension of musical time, which in Chapter 2 was contextualized within smooth and striated temporality (Boulez, 1975; Deleuze and Guattari, 1987; Hulse 2016), and embodied, situated perspectives (Phillips, 2022; Haraway, 1988). Striated time is organized by recurring markers or metric grids, whereas smooth time unfolds as a continuous, unmeasured flow. Tuplets exemplify striation by partitioning spans into equal units and inscribing additional grid lines into musical time. Through tuplets, composers and performers take decisions that shape motion, afford or constrain embodiment, and participate in a work's politics of time, which is the way a work's identity is negotiated through a shifting constellation of variables, as outlined in Section 2.5: compositional design and notation, performance practice, instrumental and bodily affordances, acoustical conditions, technologies of timing, and listening conventions.

Throughout this chapter, I examine the definitions of key tuplet types, questions of harmonicity, notational practice, metrical identity, grouping strategies, and rhythm, and I include a section on the experience of tuplets in performance and listening. I also consider speed changes between tuplets and tuplets within tuplets, and I develop performative strategies for timing accuracy and ensemble coordination.

Origins

While striation in the form of a regular pulse was likely present at the beginnings of music, the conceptual roots of tuplets at least predate the modern term by several centuries. In medieval and Renaissance mensural notation, composers already manipulated proportional relationships through *tempus*, *prolatio*, and *color*, creating durational ratios such as *sesquialtera* (3:2) and *dupla* (2:1) that effectively performed the same rhythmic function as modern tuplets (Apel, 1953, pp. 96-195). By the late Baroque and Classical periods, the proportional logic of earlier mensural notation had long given way to modern metrical notation, in which occasional numeric indications above or beside beamed groups served to mark irregular subdivisions within an otherwise regular meter. This practice foreshadowed the fully standardized tuplet notation of the nineteenth century (Read, pp. 74, 214). Here are two examples from C.P.E. Bach's *Sonata V* for keyboard, Wq. 51 (1758-1760).

[24] ...

Example 3.1. Bach, *Sonata V*, Allegro

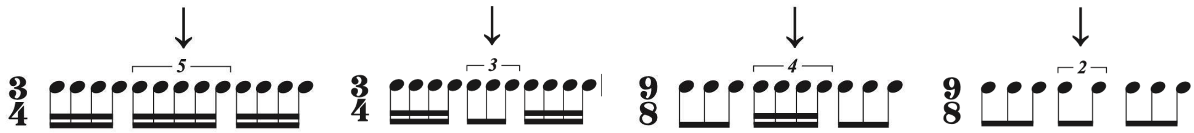
Yet the word "tuplet" itself is of much later origin, emerging in the twentieth century as a back-formation from the final element of terms such as *triplet*, *quintuplet*, and *sextuplet*. While these individual terms were already established in musical usage, *tuplet* - as a collective reference to all irregular subdivisions - did not become widespread until it entered the vocabulary of digital notation programs in the 1980s. The related expression *n-tuplets*, likely drawn from mathematical notation where *n* signifies a variable integer (as in *n*-tuple), had already appeared in a 1980 video demonstrating the *Mockingbird* music-notation system at

[24] C. P. E. Bach describes in his *Versuch über die wahre Art das Clavier zu spielen* (1949/1753–1762, p. 160) that the 18th-century convention when a written sixteenth note appears in a passage of triplet eighths, the sixteenth is assimilated to the triplet so that it aligns with the third note of the triplet group, rather than being realized as a literal two-against-three. For a detailed account of later 19th-century "impossible rhythms" created with tuplet notations, as well as practical performance solutions, see Julian Hook's article "How to Perform Impossible Rhythms" (Hook, 2011).

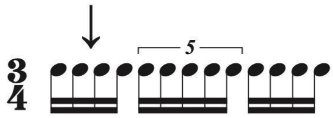
Xerox PARC.[25] When Coda Music's *Finale* was released a few years later, its interface adopted the simpler "Tuplet tool," omitting the *n* and thereby helping to canonize the modern term within the lexicon of digital notation (Coda Music Technology, 1988; mu:zines, 1989).

What is a tuplet?

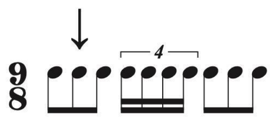
A tuplet is a group of evenly spaced divisions within a specified duration of time. This duration may be a single pulse or a shorter or a longer span.Tuplets are traditionally understood as a way of creating faster or slower subdivisions that differ from those implied by the time signature:



While musical practice and software notation programs consider tuplets as exceptions, notes defined solely by the meter also move at a particular speed. For that reason, it is useful for the general concept of speed in music to broaden the definition of a tuplet to include divisions inherent to the current meter, such as four sixteenths in 3/4, or three eighths in 9/8:



and



.

Example 3.2. Examples of tuplet and meter-based subdivisions

These are also tuplets, but since they fall within the meter they typically don't need an extra tuplet notation.

To help understand this point, consider the structural and ornamental use of tuplets in a section of my work *Rickshaw Zip*, for piccolo and piano (2015). The rhythmic phrasing in the piccolo part between letter H to I consists of 16th notes with syncopations, with a slowing down via tuplets (32nds, sextuplets, quadruplets, triplets, duplets) during the last five beats. The last beat containing two eighth notes (bar 32) forms a grouping of two which is continued through the shift to triplets at letter I: triplets in groups of two.

[25] A manual for *Mockingbird* from 1982 lists "Beams and N-tuplets" among its engraving functions (Maxwell, 1982).

Example 3.3. *Rickshaw Zip*, score excerpt

The last bar of letter I (bar 36) shifts to triplets in groups of three, emphasizing the beat in order to shift back to 16th note material at letter J, similar to H, except with a more ornamental use of triplets.

At letter K the music makes another structural shift to quintuplets, creating a floating character. This begins with quintuplets in groups of five - aligning to the beat - and later shifts to groups of two, providing a sharp quickening in accents to lead to the climactic end of the section (bar 45).

Example 3.4. *Rickshaw Zip*, score excerpt

Across these examples, metrically determined articulations are as consequential for expression and form as explicitly notated tuplets. What matters for the musical argument is the speed of subdivision and the resulting event density, rather than artifacts of notational convention. In this chapter, I use the term “event” to refer to any sounding onset in the rhythmic grid, whether pitched or unpitched, rather than only traditionally notated “notes.” Therefore, all "evenly spaced divisions within a specified duration of time" include speeds inherent to the meter, and I extend the term tuplet to include them.

While different tuplets represent different rates of notes, each subdivision also carries a distinctive character that extends beyond metronomic speed. Altering the rate by shifting from one subdivision level to another may at times produce the impression of acceleration or deceleration, as in bars 31 and 32. At other times, when the new tuplet is sustained for some time, it can structurally change the rhythmic identity of the entire passage. A shift such as moving from eighth notes to triplet eighths in groups of two, or from four sixteenths to five quintuplets, does more than alter note density; it reshapes accent patterns, symmetry, and the overall rhythmic character. In this sense, a tuplet change both modifies speed and reconfigures the rhythmic identity, shaped by a range of parameters that will be discussed in the following section.

Even and odd tuplets

The uniqueness of a tuplet is based on several parameters, starting with whether the number of divisions is even or odd. The even-numbered tuplets of two, four and eight, all have a square, marching-like character, divisible by two. This binary quality is likely inherently comfortable for humans due to our experiences walking with two legs. In addition, instruments that produce notes through alternating motion, such as the guitar, typically played by strumming, and bowed string instruments, played by bowing, make this distinction especially evident.

Odd-numbered subdivisions, in contrast, cannot be split into two equal halves. There is no natural midpoint to anchor a secondary accent. These odd tuplets therefore have a different flow: rather than a "left-right" (or "up and down") feeling, they create a sense of continuous motion that "rolls" forward into the next beat. For me, odd tuplets have a rounded, propelling character; they seem to *lead* into the following beat without the moment of repose or symmetry that an even split provides.

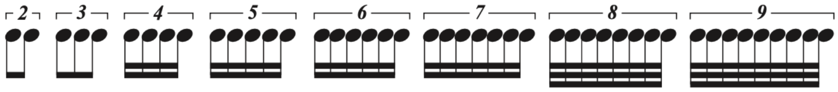
Between these categories are hybrid cases. Six can be felt as 3+3 (square and balanced, like a fast compound duple) or as 2+2+2 (more fluid and round). Nine can be perceived as 3+3+3 (regular and balanced) or as uneven groupings such as 4+5 or 5+4, giving it a more lopsided quality. Because of this flexibility, six and nine can behave as either stable or propelling, depending on interpretation.

Tuplets like four (which can be seen as 2×2), 6 (2×3 or 3×2), 8 (2×4), and nine (3×3) are sometimes termed multiplicative tuplets because their structure can be understood as multiplying smaller even/odd groupings (Barlow, 1980, p. 35). For example, eight has the structure 2×4 (even times an even), and six can be 2×3 (even times odd) or 3×2 (odd times even), etc. This multiplicative view highlights how our perception of these tuplets might combine characteristics: six subdivided as 2×3 feels like a binary framework (two main pulses) each filled with ternary (triplet) subdivisions – a mixture of square at one level and round at another.

Harmonicity and difficulty

Looking at another interpretation of tuplets, composer and music theorist Clarence Barlow developed the *indigestibility function* to measure the harmonicity of numbers and their relative difficulty in harmonic and rhythmic applications. His basic idea was that smaller numbers, or those that factor into small primes, are more "harmonic" and easier, while larger primes are more "indigestible" and more difficult. In rhythm, this means that subdividing a beat into an odd prime number of parts is harder to process than dividing it into factors of two or three. Using a formula that considers both the size of the number and its prime factors, seven (a prime) receives a high indigestibility value, while eight (2×2×2) receives a lower value. Although eight is larger, it is built from smaller primes and is therefore easier to "digest."

The results of Barlow's indigestibility calculation for numbers two through nine are as follows (a lower value means more harmonic/easier, a higher value means more complex):



Example 3.5. Duplets to nonuplets

- 2 1.0000000
- 3 2.6666667
- 4 2.0000000
- 5 6.4000000
- 6 3.6666667
- 7 10.285714
- 8 3.0000000
- 9 5.3333333

(Barlow, 1980, p. 23; Barlow, 2001, p. 6-13)

Several observations spring out from this list. It suggests, for instance, that three is only slightly "harder" (more indigestible) than eight (3.00 vs 2.67), that nine is less indigestible than five (5.33 vs 6.40), and that seven is much more indigestible than five (10.28 vs 6.40). Although this yields a tidy ordering, embodied effort and conceptual framing can lead to different outcomes. In my experience, a triplet per pulse often proves harder to perform than eight notes because it breaks duple symmetry, while eight aligns with it within a binary frame. More generally, even subdivisions (2, 4, 8, and so on) are easier to internalize than odd subdivisions (3, 5, 7, and so on), because only the even sets provide a symmetric midpoint and support left and right alternation. Moreover, five can be at least as difficult as seven, since both involve irregular groupings that resist even subdivision; I find septuplets more intuitive than quintuplets, since they often include a repeated grouping (2+2+3 or 3+2+2), whereas quintuplets require a constantly changing grouping (2+3 or 3+2). It is important to bear in mind that Clarence Barlow's indigestibility metric was intended as an objective compositional measure - "All this is part of a composer's technique" (Barlow, 2001, p. 7) - concerned perhaps with how readily a subdivision can be related by a listener to the unit pulse, rather than a test of performative accuracy.

Until now, these points have been applied to qualities of numbers that fit within a single beat. Composer Richard Barrett observes that indigestibility depends on the full ratio. Both numerator and denominator matter. For example, 6:4 is typically more digestible than 6:5 or 6:7 (Richard Barrett, personal communication, 2025). These ratio-based cases will be discussed below. Speaking as a performer as well as a composer, I experienced that quintuplets and septuplets may feel awkward at first compared with sixteenths or eighths, yet with practice they can become just as natural. The larger point is that practice effaces differences in difficulty, while the structural and expressive possibilities of each number, its accent patterns, smoothness, or asymmetry, remain salient to musical identity. In many musical traditions outside Western Classical practice, such as South Indian Carnatic music or West African drumming, these so-called "indigestible" tuplets are treated as natural and foundational rhythmic units. This underscores that cultural context and familiarity, as much as numerical calculation, determine how digestible a rhythm becomes.

Groupings

Another important aspect of tuplets is how they can be subdivided into smaller groups. Studies in rhythm show that when we hear a rapid stream of evenly spaced sounds with no accents, our brains tend to impose groupings, a phenomenon called *subjective accentuation* (Bolton, 1894; Vos, 1973; Large, 2008). Typically, sequences are heard in twos, threes or fours. This means that in long runs of notes, performers and listeners often perceive subdivisions even when none are marked.

In tuplets, these groupings emerge clearly. Quintuplets are commonly heard as 2+3 or 3+2, and septuplets as 3+4, 4+3, 2+2+3, 2+3+2 or 3+2+2. Because they cannot be divided evenly, they take on an irregular, lopsided quality, taking a step on the spectrum of temporal identity towards a smooth articulation of time. In my composition *Stone Soup* (2001), for example, I use both 3+4 and 4+3 septuplets, highlighting their asymmetry to create rhythmic tension.

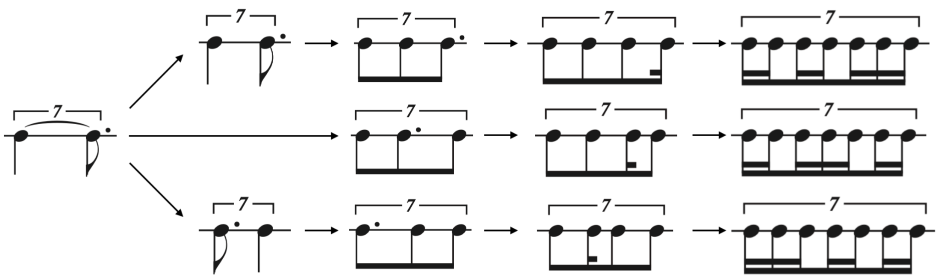
Example 3.6. *Stone Soup*, score excerpt. Audio excerpt.

Extending this point, rhythmic structure can also be parsed at multiple levels, a phenomenon Barlow terms *stratification* (Barlow, 1980). In a septuplet, a listener may apprehend the figure in one or more of the following strata.

- 1st: a single span
- 2nd: 4+3 or 3+4, (two groups)
- 3rd: 2+2+3, 2+3+2, 3+2+2, (three groups)
- 4th: 2+2+(2+1), 2+(2+1)+2, (2+1)+2+2, (each 3 broken down to a 2+1)
- 5th: constituent sixteenths

In performance, I realize this fourth stratum by internally subdividing any ternary grouping into 2+1 or 1+2. This parsing provides a reliable anchor for timing and supports accurate control of the total duration.

This practice of stratification lets composers shape accent patterns and texture while the underlying septuplet remains intact. For performers, the concurrent layers provide alternative anchors for timing, phrasing, cueing, and synchronization. For analysis, they show how one surface can project different metrical identities and, with them, different kinds of perceived speed.



Example 3.7. Stratification of septuplets

These groups manifest themselves as rhythms in the following passage of *Stone Soup* (McGowan, 2001) with additional rhythms added to the groups.

Example 3.8. *Stone Soup*, score excerpt. Audio excerpt.

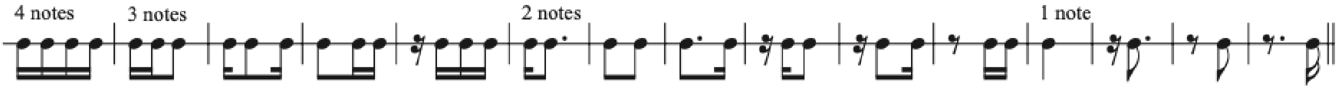
Larger tuplets admit further levels of stratification. Nonuplets (9) may be felt as 4+5, 5+4, each with their possible subgroups, or as 3+3+3, which provides a consistent ternary pulse. These groupings are not only theoretical but aid the performance: odd tuplets are easier to execute when chunked into familiar patterns, such as memorizing a long number sequence by breaking it into groups.

Rhythms

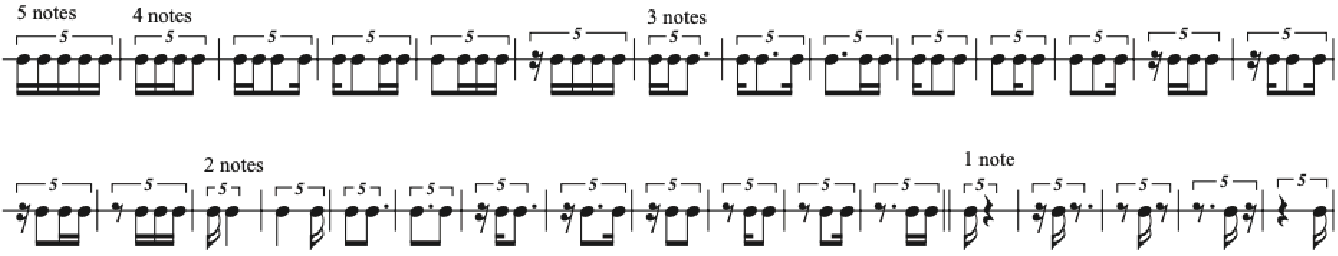
Tuplets establish the speed of a subdivision grid, but this does not in itself determine the actual event density. Not every position within the grid is necessarily articulated; some sound while others remain silent, producing rhythms through selective activation of the grid rather than its mere existence. Rhythm therefore emerges not only from the grid but from the specific pattern of sounds and silences within it. The pace of articulated events can thus diverge from the implied change in speed suggested by the tuplet.

With slurs and rests included, the following list presents rhythmic permutations in 16ths, quintuplets, sextuplets, and septuplets with 16th notes and longer. Each tuplet yields variations according to the number of notes, and with larger tuplets the number of possible permutations increases.

16ths

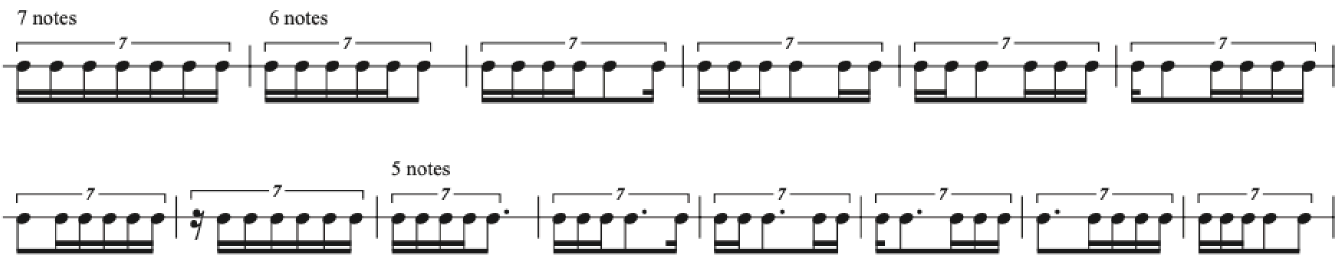


Quintuplets



Sextuplets

Septuplets




4 notes
3 notes
2 notes
1 note

Example 3.9. Rhythms within tuplets

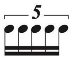
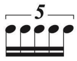
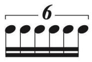
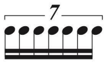
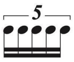
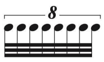
To conclude: *each tuplet carries a distinct rhythmic character*, shaped by parity (even or odd), harmonicity, possible groupings, and the specific rhythms employed within the tuplet grid. Quintuplets differ from septuplets as much as an apple differs from a banana - both fruits, yet distinct in flavor. As Steven Schick observes in *The Percussionist's Art*:

> 7:6, for example, has a very different kind of rhythmic personality than does a duple subdivision at exactly the same speed. It's a question of feel. (Schick, 2006, p. 106)

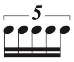
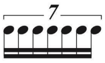
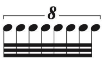
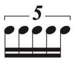
In other words, perceived identity is not only a matter of how many notes fit in a beat or how fast they proceed; parity, grouping, and accent combine with other musical parameters such as articulation and timbre to produce each subdivision's unique feel. These contrasts can be heard in my work *The Speed of Time* (2014), which cycles through different tuplets and changes only at the bar lines.

Example 3.10. *The Speed of Time*, score and video example.

3.2 Changing tuplets in music

Switching between different tuplets can be a valuable expressive tool, creating a clear change in the visceral sensation of speed. Although this effect is familiar to performers, the specific speed change that occurs when moving from one tuplet to another is rarely described explicitly. Each pairing of tuplets yields a distinct proportional change in speed: some shifts produce dramatic increases in perceived speed, while others result in more subtle differences. One perspective rarely articulated is to translate those qualities into quantities, looking at tuplet changes in percentages. For example, moving from  to  is 33% faster, which is already substantial; from  to , the next step up, is 25% faster; and from  to  still 20% faster. Non-consecutive transitions can yield much larger jumps: from  to  is 75% faster, and from  to  60% faster, and so on.

The same combinations getting slower produce negative percentages:

-  to  is 25% slower, or -25%
-  to  is -20%
-  to  is -43%
-  to  is -37%

Each change in tuplet speed carries its own distinct physical quality, comparable to shifting gears in a vehicle: the pace changes are not only quantitative but also alter the sensation of motion and the stability of any underlying pulse. These qualitative differences can be an important expressive element in music.

The following chart emphasizes that there is no single consistent speed adjustment that applies to all tuplet transformations. For performers, each must be embodied and learned through repetition, and awareness of the degree of speed change can be a helpful guideline.

to

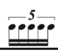
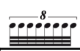
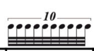
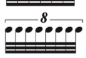
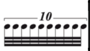
												
		100%	200%	300%	400%	500%	600%	700%	800%	900%	1000%	1100%
		50%	100%	150%	200%	250%	300%	350%	400%	450%	500%	550%
		33%	67%	100%	133%	167%	200%	233%	267%	300%	333%	367%
		25%	50%	75%	100%	125%	150%	175%	200%	225%	250%	275%
from		20%	40%	60%	80%	100%	120%	140%	160%	180%	200%	220%
		17%	33%	50%	67%	83%	100%	117%	133%	150%	167%	183%
		14%	29%	43%	57%	71%	86%	100%	114%	129%	143%	157%
		13%	25%	38%	50%	63%	75%	88%	100%	113%	125%	138%
		11%	22%	33%	44%	56%	67%	78%	89%	100%	111%	122%
		10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	110%
		9%	18%	27%	36%	45%	55%	64%	73%	82%	91%	100%

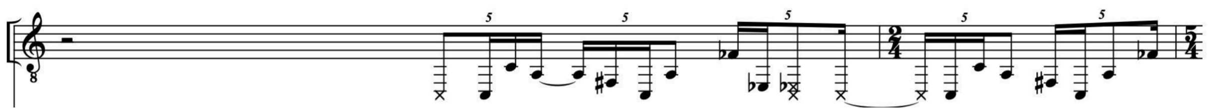
Figure 3.1: Speed adjustment chart

As shown in Figure 3.1, the percentages describe how much faster or slower the surface becomes, but they only capture one aspect of how tuplet changes are experienced. An equally important factor is how the underlying pulse is organized or disrupted. A move from duplets to triplets over the same pulse, for instance, can produce a large increase in event rate while leaving the sense of a stable beat largely intact. By contrast, a move from sextuplets to septuplets over the same span may involve a smaller numerical change in speed, yet it can significantly destabilize the underlying pulse. In such cases, the "digestibility" of particular ratios, and the possibility of reinterpreting the pulse through metrical modulation, can be equally or more perceptually relevant than the raw percentages. These relationships are further conditioned by the surrounding musical context, in particular whether an audible or conducted reference pulse is maintained elsewhere in the music.

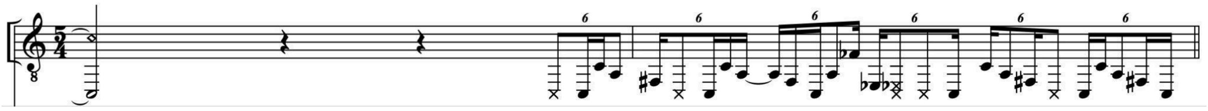
In the following sections from the guitar part of Riccardo Nova’s *Primes Seventeen* (2010-14), for guitar, percussion, and electronics, musical material is played by the guitar in sections that sequentially increase in tuplet and thus speed: 16ths, quintuplets, sextuplets, 32nds and nonuplets. The speed changes from one bar to the next are given.

Bar 30 (2’04”): initial tempo

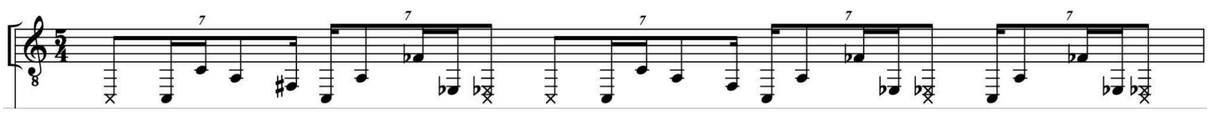
Bar 33 (2’15”): 25% faster



Bar 39 (2’37”): 20% faster

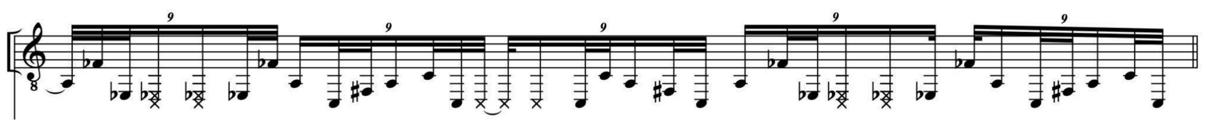


Bar 47 (3’06”): 17% faster



Bar 54 (3’35”): 14% faster

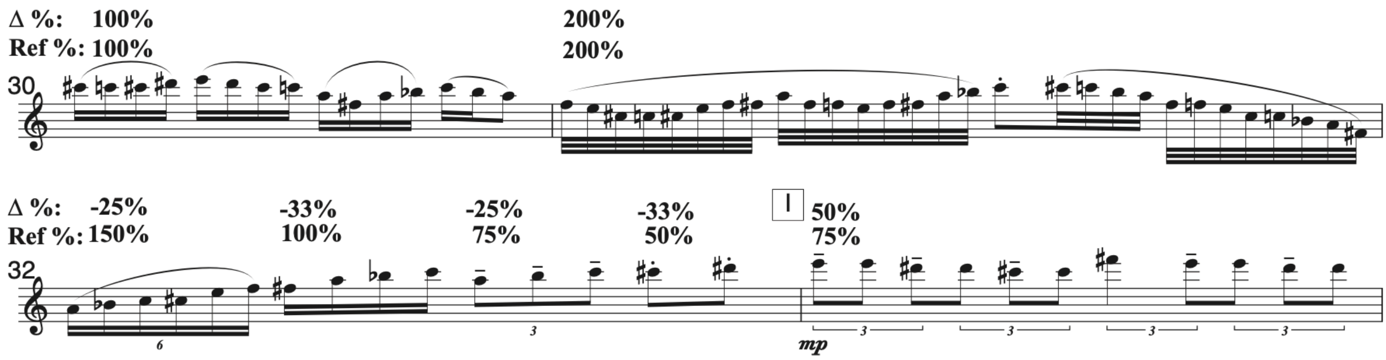
Bar 64 (4’11”): 13% faster



Example 3.11. Nova, *Primes Seventeen*. Video.

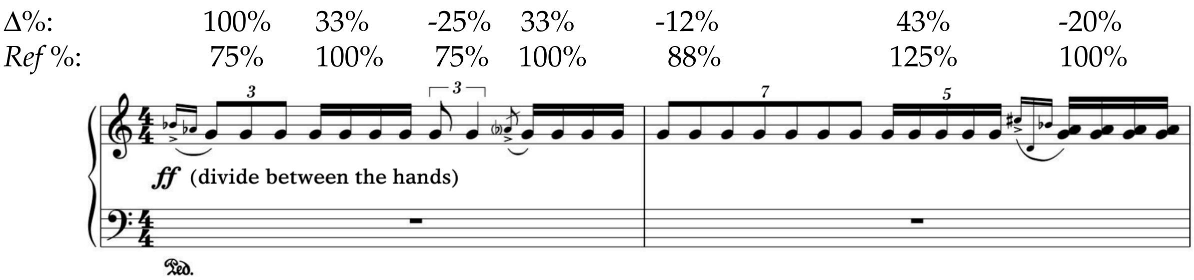
The increase in speed from 16th notes to quintuplets is 25%. Subsequent changes in speed result in smaller increases: 20%, 17%, 14%, and finally 13% from 32nd notes to nonuplets. Translating the quantities back to qualities, the differences are significant, since the smaller percentage increases involve subtler shifts in energy and articulation, whereas the jump from 16th notes to quintuplets produces a more striking acceleration that can feel both technically demanding and expressively dramatic.

Another example of reflecting the percentage of speed changes between tuplets appears in my work *Rickshaw Zip*, for piccolo and piano. The piccolo makes the following shifts: 100% → 200% → -25% → -33% → -25% → -33% → 50%. I describe this as the *change percentage* (Δ%), showing how much faster or slower each step is compared with the previous one. A second perspective, useful when there is a dominant speed in the music, is to relate every tuplet in the passage to a single reference value (*ref* %). Here, 16th notes serve as the baseline, producing a different series where each percentage relates to the 16th note speed: 100% → 200% → 150% → 100% → 75% → 50% → 75%. Both methods provide performers with relationships between the tuplets that can guide their interpretation and performance. The Δ% method highlights the immediate contrast from one beat to the next, which is especially helpful when clarity of transition or articulation of a sudden acceleration or deceleration is needed. For example, in the sequence from 200% to 75%, the Δ% view emphasizes the dramatic drop of more than half, drawing attention to the abruptness of the change. The ref % method, by contrast, situates all tuplets in relation to a common baseline, which in this case reframes the same move as a shift from 200% to 150% - a less extreme difference that shows how the passage still remains relatively close to the reference pulse. In performance, Δ% is often more practical for moment-to-moment navigation, while ref % is more useful for understanding larger-scale proportions and planning phrasing.

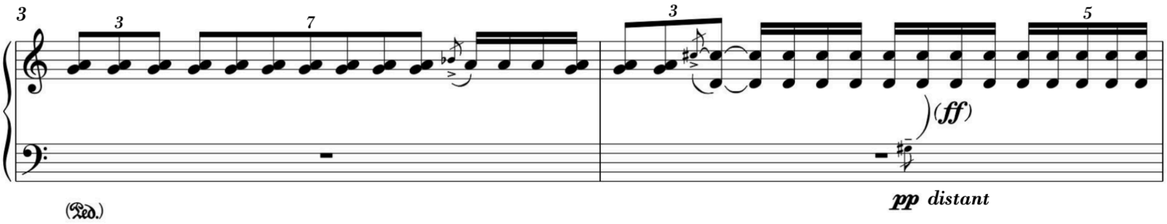


Example 3.12. *Rickshaw Zip*, score excerpt. Audio excerpt.

The speed changes in *Rickshaw Zip* are deliberately consistent, almost metronomic, because the stable rhythmic grid established by the piano and piccolo anchors the flow. Applied to a solo piece, the same analytical perspectives can allow more flexibility in realization. Take for example the opening bars of Augusta Read Thomas's piano etude *Twitter-Machines* (2005), where the tuplet changes each beat. Both percentage methods are written above the passage: Δ% shows the change from one beat to the next, while *ref* % relates each speed to 16th notes. This clarifies how the music alternates between local contrasts and its relation to an overall reference pulse, giving performers two complementary perspectives on the flow of speed changes.



Δ%: -25% 17% 14% -25% 33% 25%
Ref %: 75% 88% 100% 75% 100% 125%



Example 3.13. Thomas, *Twitter-Machines*

Thomas's score goes a step further by adding an explicit note on speed that permits flexible realization of the notated percentage changes.

> ♩ = 120; or, **As fast as possible**, if 120 is too fast (tempo **should** be variable and does not have to be stable from measure to measure. This will add to a "twittering" and "jazzy" effect.
> (Read Thomas, 2005, bold in original)

Performers may choose to exaggerate the speed changes to bring out "twittering" or "jazzy" effects. As with expressive timing marks such as *rubato* or *ad lib.*, it is usually advisable first to learn the rhythms as written, and then apply timing expression. In a piece such as *Twitter-Machines*, where no familiar stylistic model dictates how these variations should sound, such choices are guided less by an external genre template than by the internal criteria of the piece: the proportional relations indicated in the score, the physical feel of the gestures under the hands, and local cues such as contour, articulation and dynamics. In this process, the speed percentage methods can serve as a practical aid.

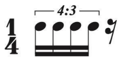
The notation must therefore be read holistically: not only the tuplets and instructions, but also meter, beaming, articulation, dynamics, registral contour and phrasing together shape the intended motion; the percentage indications function within this notated ecology rather than as an autonomous layer.

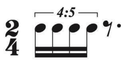
Using tuplets to change speed opens a continuum of rhythmic expression that is distinctive. Unlike altering tempo by arbitrary amounts, tuplets shift speed through exact proportional ratios, giving each change its own signature. Even adjacent tuplets produce not only a new speed but also a new character, shaped by factors such as even/odd distinction, harmonicity, grouping, and articulation. While 6 cm and 7 cm may appear nearly identical in spatial terms, a sextuplet and septuplet diverge markedly in rhythm because of their grouping and momentum. Tuplets therefore act like a dial that clicks into distinct positions, each one a unique expressive setting. This blend of proportional speed change and qualitative character provides a rich palette of resources for composition and performance.

3.3 Ratio tuplets
As briefly mentioned above, all tuplets are in fact ratios and most of the examples above imply the second number as the same number subdivision as the note value typical in one beat:

- three (triplets) - 3:2
- four (quadruplets, or often 16ths) - 4:4
- five (quintuplets) - 5:4
- six (sextuplets) - 6:4
- seven (septuplets) - 7:4
- eight (octuplets, or often 32nds) - 8:8
- nine (nonuplets) - 9:8

This can be conceptualized as a box model: the second number indicates the size of the box in units of the base note, and the first number indicates how many equal elements fill that box. If the base unit is not stated, it is inferred from its context, such as the subdivision of the beat as given by the meter and the number of available beats in the meter. Thus the two numbers in a ratio tuplet work together, the second showing the span of time and the first the number of divisions within it.

In addition to tuplets which fill one or two beats completely, the technique also permits more localized speed changes which may assume fractional beat lengths, notated as a ratio: those can be shorter than a beat, e.g. 

or longer: 

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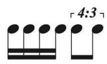
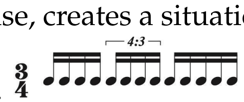
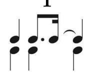
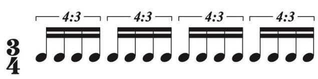
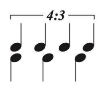
Crucially, a tuplet determines the speed of the rhythmic grid rather than the number of articulated notes, and the pace of the sounding rhythm can operate independently of that grid. When the grid is understood as a separate rhythmic layer, it can likewise expand or contract, just as a rhythm can grow denser or more diffuse.

In the following example, the tuplet is written as 4:3 rather than 2:3: 

. The grid accelerates by 33%, yet the articulated notes are twice as long, so the sounding rhythm is slower than the preceding sixteenths despite the denser subdivision. Tuplets therefore articulate transformations in the metric framework or felt pulse more than they prescribe literal note density, allowing composers to play creatively against the grain of the tuplet. Tuplets also unsettle the proportional relation of two to one in notated rhythm (for example sixteenth to eighth or eighth to quarter), which can lessen the visual clarity of the bar. This idea is explored further in the 'tuplets within tuplets' section.

Ratio tuplets can create beats which have different lengths than implied by the time signature. These beats establish their own frame of pulses, which, together with the main pulse, creates a situation of multiple simultaneous pulses. These layers of pulses can be in syncopation: e.g. 

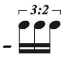
creates 
- or in a series, which can establish a polypulse: 

becomes 

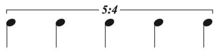
. This introduction of irregularities in the implicit grid has the same effect as the explicit irregularities possible with rhythms, which gives tuplets a similar role in defining striated and smooth time.

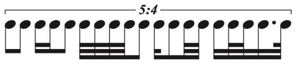
Tuplets do not abandon metric striation so much as re-striate it: they replace one pattern of equal subdivision with another, locally incompatible one. For the performer, this produces a second, precisely countable grid that can be executed with high accuracy. For the listener, however, the rapid alternation between competing subdivisions can weaken the salience of any single underlying pulse and be heard less as a clean change of grid than as a momentary “softening” of metric regularity. In that sense, tuplets can yield brief passages of perceptual smoothness within an otherwise striated temporal field, even though their production remains fully metrically specified.

Striation and frame tuplets

I differentiate between *striation* tuplets and *frame* tuplets. By striation tuplets I mean ratios that subdivide a duration into a different speed at the subdivision level, creating a local grid distinct from the larger metrical frame. For example, 3:2 - 

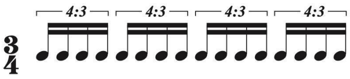
- as a striation tuplet indicates three sixteenth notes in the time of two sixteenth notes, essentially the standard triplet rhythm within one eighth note. Most of the examples until now represent this approach.

Conversely, a *frame tuplet* refers to beats or time spans that carry rhythmic figures. For example, 5:4 quarter notes - 

- means five quarter-note beats in the time of four quarter-note beats. When those beats contain their own subdivisions and rhythms, the tuplet functions as a frame tuplet:


. The ratio establishes a new metrical frame or tempo that runs in proportion to the original. In rehearsal and performance this difference is tangible: striation tuplets are usually felt as faster or slower activity within a stable tactus, whereas frame tuplets invite performers to adopt the tuplet layer itself as a new pulse, with consequences for how they count, cue, and coordinate with others.

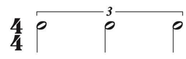
In principle, many frame tuplets could be rewritten as striation tuplets, and some editors would indeed prefer that for the sake of visual uniformity. The usefulness of the distinction in my work is therefore not notational but functional. When I compose with striation tuplets I am primarily coloring the density and articulation of an existing pulse; when I use frame tuplets I am thinking in terms of proportional tempi and multiple simultaneous pulses that may be sustained, phased against one another, or brought back into alignment. The terms are best understood as perspectives, one more local and the other more extended, that name two different compositional and performative functions rather than two different species of notation.

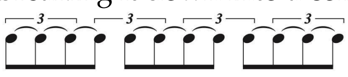
With some ratio tuplets the subdivision of the main pulse no longer results in a whole number. For example, in 

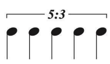
sixteen notes spread evenly across three beats work out to a little more than five notes per beat, rather than a whole-number subdivision. Such fractional tuplets create a floating quality in relation to the main pulse. They also render traditional subdivision techniques impractical, requiring other strategies for performance, such as focusing on larger frames, as will be discussed below.

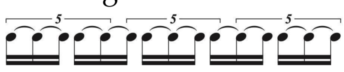
Contextualizing further, frame tuplets create additional layers of temporality. Striation tuplets define grids of different speeds at a surface level, whereas frame tuplets establish a new layer of striation that differs both from the surface-level subdivisions and from the underlying meter and pulse. In this way, frame tuplets provide a distinct temporal dimension, adding complexity beyond the immediate articulation of rhythm.

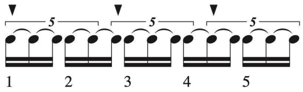
Tuplet and grouping

A common method to perform tuplets in practice, such as 

, is to approximate the placement of the notes across the entire span (here one bar), often with some unevenness. This can be understood as producing smooth time. This rhythm, however, can be performed with absolute striated accuracy by breaking it down into a combination of tuplet and grouping, in this case, triplets in groups of four:


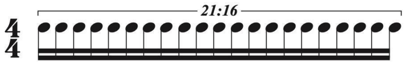
. The tuplet brackets indicate the beat positions, while the beaming shows the note lengths. In similar fashion, a 5:3 - 

- can be conceptualized as quintuplets in groups of three:


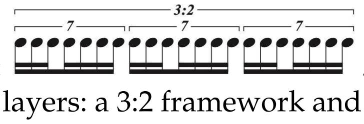
. The rule therefore is: a ratio tuplet of x:y is x tuplet in groups of y. In order to perform these accurately, a method of counting the groupings and determining where the beats fall is very helpful: 

. The arrows reinforce which notes within the groupings coincide with the beats.

Frame reductions

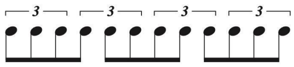
In some cases, ratio tuplets with larger numbers of notes cannot be simplified through the earlier methods. For example, in 21:16, 

, the combination of tuplet and grouping (ventiunplet (21) in groups of 16) is impractical at this speed. When reduced to a repeating tuplet within one beat (21 ÷ 4), the result is 5¼ notes per beat, slightly faster than quintuplets. Such an approximation provides a useful calibration to begin with, which can then be refined.

Since 21 equals three septuplets and 16 spans two half notes, one way to reconceive this ratio is to place septuplets within a 3:2 frame: 

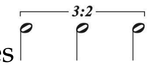
. This reduces the complex tuplet to a combination of two relatively manageable layers: a 3:2 framework and septuplets.

Learning to perform this, one can proceed in steps:

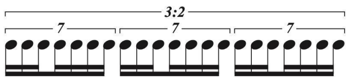
- a: Practice triplets in groups of four: 

.

- b: Reduce that to the 3:2 frame: 

becomes 

.

- c: Insert septuplets into that frame: 

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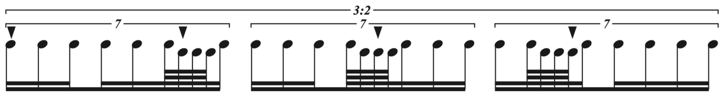
- d: For further refinement, an awareness of exactly where the beat falls is helpful:



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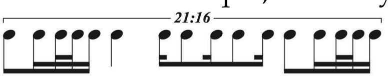
Speed percentage

As mentioned above, calculating the percentage of speed change can also be useful.

In the 21:16 example, if the rhythms are grouped differently than three septuplets, 

, the 3:2-with-septuplets strategy is less practical. The speed change from 16 to 21, though, is an increase of 31%. For comparison, quintuplets are 25% faster than quadruplets and sextuplets 50% faster, so the 16th-note speed of the passage is only slightly faster than quintuplets. Establishing the quintuplet 16th-note speed for the figure therefore brings one very close to the actual speed (+6%).

Another example that does not reduce to a simpler frame is 17:16, since 17 is a prime number. Here it is straightforward to recognize that 17th notes are just slightly faster than 16th notes (about a 6% increase), which provides a practical reference. The tuplet 17:16 also has a floating quality, as no notes align with the beats throughout.

An interesting challenge from musical literature is several bars from Xenakis' ensemble piece *Thallein* (1988):

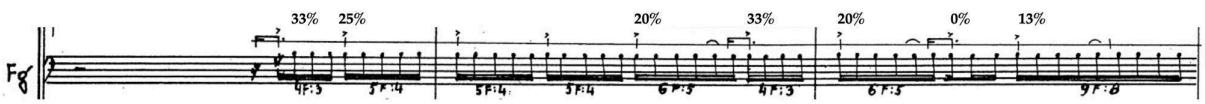
Example 3.14. Xenakis, *Thallein*, score excerpt (full score). Video.

In this passage, the bassoon part plays in rhythmic unison with the strings yet moves at a subtly different speed from the other two instrumental groups: the upper woodwinds and piano, and the brass.

Example 3.15. Xenakis, *Thallein*, score excerpt (bassoon part).

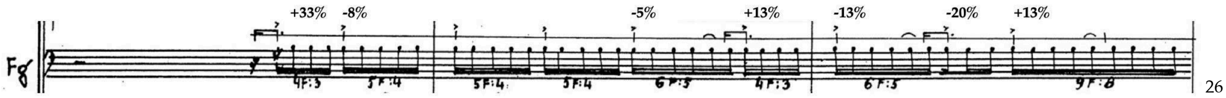
Each tuplet changes speed - 4:3 → 5:4 → 6:5 → 4:3 → 6:5 → 16ths → 9:8 - producing a series of subtle accelerations and decelerations. The notated lengths of each group above the staff clarify where speed changes occur, but indicating the relative percentages of these shifts can make the transitions clearer to the performer.

Two approaches are possible: the first compares all tuplets to a common reference, such as the 16th note; the second measures the percentage change between successive tuplets, indicating both the direction and magnitude of each shift. Positive percentages indicate acceleration and negative percentages indicate deceleration.



Example 3.16. Xenakis, *Thallein*, score excerpt.

Another approach is to measure the percentage change between successive tuplets, which indicates both the direction and size of each shift. Positive (+) values mark accelerations, while negative (–) values indicate decelerations.

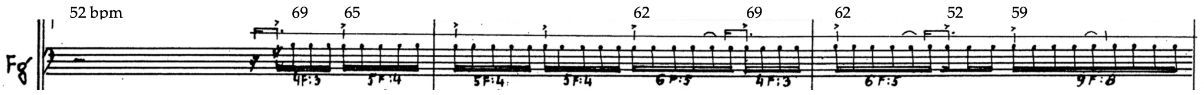


Example 3.17. Xenakis, *Thallein*, score excerpt.

The speed changes produce delicate shifts in musical character, and the percentage technique provides a precise way to both describe and conceptualize these subtle transformations.

Changes in tempo

Instead of describing speed changes as percentages, the same passage can also be expressed as a series of tempo shifts. This involves creating a tempo map as a practical shortcut: with the main tempo set at 52 bpm to the quarter note, each different tuplet corresponds to a distinct tempo.



Example 3.18. Xenakis, *Thallein*, score excerpt.

This approach has been used by performers Irvine Arditti and Steven Schick to navigate the nested tuplets in the music of Brian Ferneyhough (Schick, 2006, p. 104; Arditti & Platz, 2013, p. 88).

Speed combinations as harmony

Other advanced, more personalized approaches for performing tuplets also exist, such as developing an embodied harmonic interpretation to regulate speed combinations. The harmonicity of intervals dates back two and a half millennia to Pythagoras. Henry Cowell more recently discussed possible "scales of rhythm" in *New Musical Resources* (Cowell, 1996 [1930], p. 98), and Stockhausen extended this idea by systematizing scales of rhythm within his serial practice, treating durations as proportional series analogous to pitch collections. In his lecture *…how time passes…* (Stockhausen, 1957 [1959]), he further conceptualized a continuum between rhythm and pitch, in which changes of speed transform temporal intervals into audible frequencies. A further comparison of their theories can be found in Chapter 4. Barlow proposed that musical speeds and rhythmic ratios can also be understood in terms of harmonicity, treating temporal intervals analogously to pitch intervals so that changes in speed resemble shifts in harmony (Barlow, 2001, p. 6). In fact, what Barlow describes as the 'indigestibility' of certain tuplets relates precisely to this point: it reflects a translation of the harmonicity of just-interval ratios into proportional relationships between tuplet speeds.

[26] This is based on the percentage of a/the change formula: C=(x-y)/y, where y is the first speed, x is the second speed and C is change.

As Schick explains in performing Michael Gordon's *XY*, he experiences the ratio of speeds similarly to the ratio of pitches in intervals. For example, a perfect fifth of two pitches occurs with a frequency ratio of 3:2, which is also a rhythmic triplet. Instead of a direct translation between rhythm and pitch frequency, Schick experiences the changing tuplets as a harmonic sequence where "dissonant" rhythms, such as 6:5, can resolve to "consonant" rhythms, such as 3:2 (Schick, 2006, p. 77).

Example 3.19. Gordon, *XY*, score excerpt. [Audio] (approx. at 9 minutes and 15 seconds).

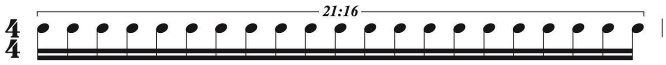
This "harmonic" perspective does not directly provide a counting method, but it offers an expressive guide and a conceptual justification for phrasing and for why one combination might feel harder than another. A rhythm may feel unstable and more difficult to coordinate because it is "dissonant" rhythmically, just as dissonant intervals create beats and roughness in sound.

3.4 Tuplets within tuplets

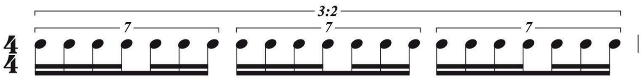
In essence, ratio tuplets create new rhythmical grids, compressed or expanded, which in turn can also contain their own tuplets, leading to *tuplets within tuplets*, also known as *nested tuplets*.

For example, take the earlier 21:16 example, first as one bar of twenty-one 16th notes:

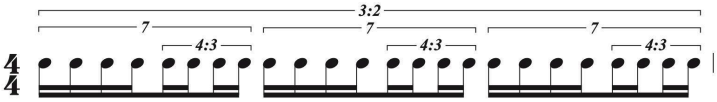
Compress that with a tuplet into a bar of 4 beats:



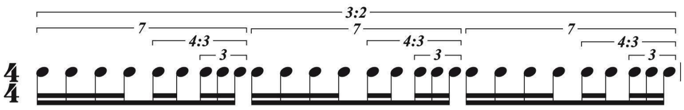
Break the 21 notes into three groups of 7 (grouped 4+3), which are placed into the 3:2 frame (3 half notes in the time of 2 half notes).



Add a 16th to the groups of 3, compressing it with a 4:3.

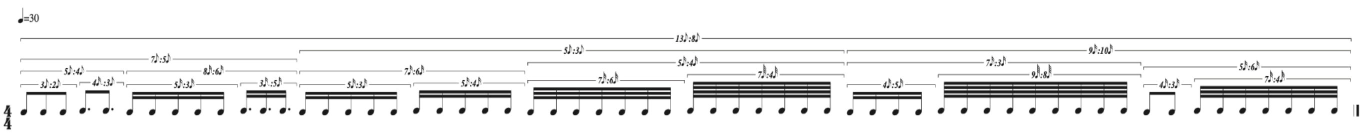


Add a 16th note to the last group of 2, compressing it into a triplet.



Example 3.20: Frames of 21:16.

This process of grouping and embedding tuplets can be approached in many ways. The above example reflects the logical rhythmic development characteristic of Carnatic music, where multiple rhythmic layers are constructed hierarchically in a way that is relatively straightforward to conceptualize and to coordinate in performance. With more complex combinations, however, tuplet-within-tuplet structures demand alternative conceptual strategies for performance.



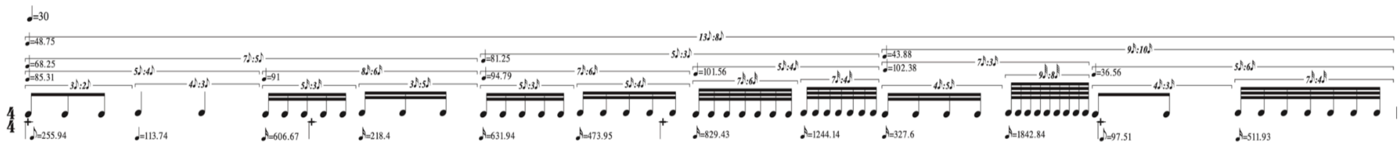
Example 3.21. Complex tuplets within tuplets. [Video](#).

In this multilayered jungle of tuplets within tuplets, references of how the speed compressions and expansions relate are lost in the large amount of irregular changes. A more graphic representation, where the beats are clearly marked and the proportional speed relationships are visually represented, can illustrate these changes with greater clarity.

Graphic placement of notes according to the beat:

Example 3.22. Complex tuplets within tuplets. [Video](#).

In the next notation, I have included the tempi of the frame tuplets, the rhythmic tuplets, and the individual note speeds. These provide useful tempo references for the various layers. However, this approach essentially bypasses the tuplet groupings, reducing the musical function of the tuplet to a tempo change. While it can be helpful for understanding the absolute notated speed of the notes in relation to the general tempo, it tends to diminish the metrical, beat-related, or agogic accents that may play an important expressive role in the music.



Example 3.23. Complex tuplets within tuplets. [Video](#).

In this example, the relative speed of note values varies greatly throughout the measure. Durations of specific note lengths (such as eighth notes) are not standardized, and in some comparisons shorter note lengths in one part of the measure are slower than longer note lengths in another. In conventional notation, rhythmic values follow a clear 2:1 hierarchy - sixteenth notes to eighths to quarters - forming a stable proportional framework. Tuplet notation, however, disrupts this hierarchy by altering the temporal equivalence of note values between different tuplets, so that the same written note value can signify different actual speeds depending on its tuplet context. This is both the essence and the musical potential of tuplet writing: it opens expressive possibilities by changing the temporal rate at which events occur, enabling transformations of rhythmic character. At the same time, it creates visual and conceptual complexity, since identical note values can represent different speeds depending on the tuplet that contains them. This destabilization requires heightened attention from the performer to how rhythmic relationships shift across changing grids, particularly in tuplet-within-tuplet situations.

Building on the previous discussion of how tuplet notation reshapes proportional relationships and performance perception, I concluded Section 3.3 by outlining strategies for executing speeds accurately. Yet beyond calculation, the most effective guidance for a performer comes from understanding why the music is notated as it is. Notation itself functions as expressive communication, and insight into a composer's rhythmic reasoning helps shape interpretation. Recognizing how rhythmic intricacy interacts with other active musical parameters allows performers to engage more deeply with the expressive logic of the notation. For instance, in the complex tuplet example above, a performer who understands which layer carries the principal melodic contour and which layers function as background can decide to project the frame tuplets dynamically while allowing inner subdivisions to recede, rather than attempting to give every event equal weight. In my own ensemble writing, awareness that certain nested tuplets are derived from Carnatic rhythmic structures can similarly encourage performers to phrase across the bar in seven-note groups instead of defaulting to the notated meter. Comprehending the compositional rationale behind notational choices connects the performer to the composer's expressive intentions and supports interpretive decisions that align with the work's larger structural and aesthetic design. For a detailed discussion of tuplet-within-tuplet phrasing from both technical and musical perspectives, see "Developing an interpretive context: Learning Brian Ferneyhough's *Bone Alphabet*" (Schick, 1994).

3.5 The experience of tuplets

Throughout this chapter I have approached tuplets from the perspectives of performer and composer, addressing embodied practices of execution and the compositional strategies that give them form. From that perspective, a further distinction becomes necessary: the experiential difference between making and hearing.

Performers and listeners experience tuplets differently. For performers, a tuplet may register as a polyrhythmic juggling act, a shift in the internal grid, or a change in feeling, depending on the implementation and on bodily or technological constraints. Techniques for precision include subdivision strategies, embodied cues, and ensemble entrainment. These techniques are themselves situated and may shift from practice room to stage, from a dry studio to a reverberant hall, or from acoustic to amplified contexts.

For listeners, the same tuplet may register as quickening or slackening, a burst of energy, a stretched gesture, or a moment of rhythmic disorientation. Perception is shaped by factors such as sightlines, distance from the sources, timbral blend, acoustic masking, and learned expectations of meter and style. In some concert-hall seats a layered tuplet texture reads as surface complexity; elsewhere it fuses into a single flow with altered accentuation.

These contrasts are only a starting point. A situated perspective, in the sense illuminated by Haraway (1988), reminds us that perception and action are partial, embodied, and specific to concrete configurations of bodies, tools, and environments. Tuplets do not exist within a simple binary between performer and listener. Situatedness involves many parameters that jointly determine what tuplets afford and how they are experienced: bodily state (fatigue, breath, embouchure, injury), learned habits and stylistic training, instrument and setup, notational design and rehearsal annotations, ensemble coordination and leadership, technological mediation (microphones, monitors, click tracks, headphones), spatial and acoustic conditions (room size, reverberation, stage layout, audience proximity), the institutional setting (concert conventions, rehearsal time, venue etiquette, amplification norms), and audience expectations (genre literacy, polyrhythm familiarity, ambiguity tolerance, virtuosity norms). The same performer will not experience the same tuplet identically across situations, and different listeners within one hall may hear different rhythmic identities depending on location, attention, and prior enculturation.

The LEMI frame (Phillips, 2022) clarifies this, provided that each facet is understood as plural and dynamic. Listeners include diverse auditory vantage points and histories. The environment includes acoustics, architecture, and technologies. The musical stimulus includes notation, timbre, tempo, articulation, and density. Interaction refers to how these elements continuously affect one another during performance. Under such conditions, tuplets are not abstract ratios alone; they are lived and enacted by performers and perceived in multiple, likely divergent, ways.

The significance lies both in the gap and in the coupling between performed structure and perceived effect. For composers and performers, tuplets constitute a versatile resource rather than a device with a single expressive function. They may be used to sculpt narrative arcs of tension and release, to differentiate voices or registers, to accommodate instrumental idioms, to translate speech or poetic rhythms, or simply to introduce local color and complexity. At the same time, listeners absorb these constructions through situated hearing that may or may not track the notated ratios. Such hearing is most often shaped by factors beyond notation. Understanding the experience of tuplets therefore requires awareness of the situation: who is acting or listening, with which bodies and tools, in which space, and under which notational and social constraints.

Despite the technical explications in this chapter, tuplets therefore do not possess a single experiential identity. They take on multiple identities as affordances for action and perception that emerge from specific arrangements of listeners, environments, musical materials, and interactions. Accordingly, claims about "how a tuplet sounds" must be anchored in the concrete situations that produce them. This situated variability does not weaken the analytical account developed earlier in the chapter. It clarifies what that account is for, namely to describe the temporal constructions that performers implement and listeners encounter under changing conditions.

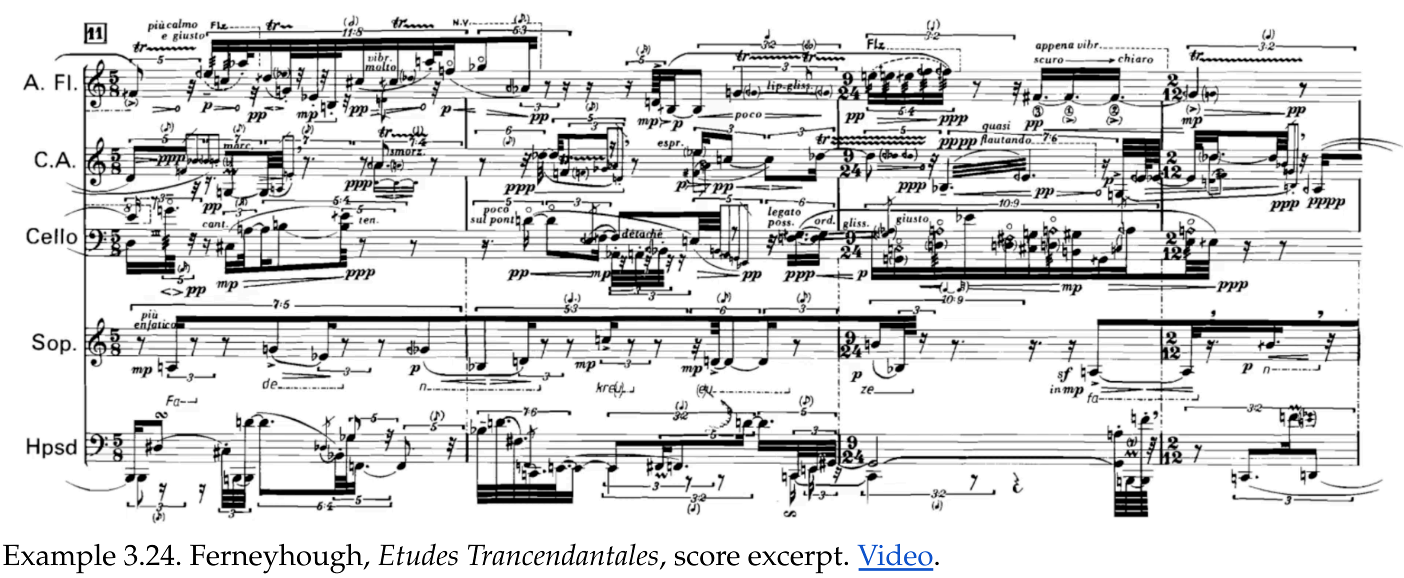
3.6 Conclusion

The preceding section points toward the chapter's central claim: tuplets are regulated subdivisions that contribute to striated musical time, yet their musical identity is realised in practice through bodies, instruments, notation, rehearsal processes, acoustics, and listening positions. On that basis, the chapter's main contributions can be stated as follows. An expanded definition is proposed in which tuplets include irregular note divisions as well as conventional metric subdivisions. Percentage change in the local event rate between tuplets is introduced as a practical way of comparing their effects on perceived speed and feel, alongside approaches based on least common multiple relationships. The chapter also addresses harmonicity, rhythmic possibilities, grouping strategies, ratio tuplets, striation and frame tuplets, and tuplets within tuplets. Together, these topics provide the basis for the conclusions that follow.

Tuplets emerge as far more than a notational curiosity; they are a creative tool of enormous power in shaping musical time. By altering the subdivision of a musical moment, tuplets allow composers and performers to morph the perceived speed and feel of the music, effectively playing with the listener's sense of speed while the underlying pulse might remain unchanged. In doing so, tuplets can even significantly change the identity of a musical idea: a melody played in triplets has a different character than the same melody in straight eighths or quintuplets. It is like the same sentence spoken with a different rhythm or accent, conveying a new expression.

Tuplets also introduce structural changes, such as new accent patterns and new points of synchronization or non-synchronization. The uniqueness of each tuplet's feel can be harnessed for contrast and expression, and the challenge of performing them has led to various solutions, ranging from mathematical to embodied methods. In this sense, tuplets compel musicians to engage deeply with time at a granular level.

From a broader theoretical standpoint, tuplets epitomize striated time, subdividing the musical grid into varied increments. As mentioned in the discussion of smooth and striated time in Chapter 2, changes in rhythms place the music's temporal quality on a spectrum between these poles. While tuplets are implied subdivisions that reveal themselves only through musical events, transitions between them also create irregularities, positioning those moments along the same spectrum of smooth and striated time. When tuplets occur within tuplets, as in Brian Ferneyhough's ensemble writing, the resulting network of ratios can generate such a dense web of conflicting striations that the underlying metric scaffolding becomes obscured and the surface approaches an impression of smooth time for listeners.



Example 3.24. Ferneyhough, *Etudes Trancendantales*, score excerpt. Video.

In such passages, the same notational devices that demand extreme striated precision from performers function perceptually to erode the sense of a stable grid. In his own compositional practice, Barrett describes how tuplets can be utilized to approximate logarithmic tempo scales, achieved through successive proportional changes (Barrett 2019, pp. 18–19), which likewise tend to efface regular points of coincidence and contribute to a continuously shifting, almost smooth temporal flow.[27] More generally, the temporal richness of nested tuplets arises from multiple simultaneous layers of implied speeds that may either reinforce or blur metric regularity. By contrast, in music that moves without any sustained pulse or floats in free rubato, the concept of tuplets ceases to apply directly, since there is no operative grid to subdivide. In this light, tuplets can be understood both as markers of metric regularity and as tools that can saturate and even destabilize that regularity: the more extensively they are deployed, the more intricately interwoven the temporal fabric becomes.

In summary, tuplets remind us that musical time is not fixed but elastic. By subdividing durations in varied ways, they create speed shifts within the notated grid, with departures from and returns to that grid. Even the most complex rhythms, once mastered, become part of a performer's natural vocabulary. At that point, musicians treat tuplets as an expressive resource for shaping perceived speed, phrasing, and accentuation, rather than as a technical device to be executed. The aim of exploring tuplets is precisely this: to internalize these ratios so that they become second nature and are ready for expressive use. When this happens, the categories "normal rhythms" and "tuplet rhythms" dissolve, leaving only rhythmic expressions with different speeds and characters at the musician's disposal. This clarifies that tuplets are a valuable tool for working with speed in music.

[27] Barrett's approach is explored further in Chapter 4.

Chapter 4: Polytempo Music

4.1 Introduction

As rhythm plays a principal role in my composing, performing, and teaching, I examine not only the relationships between conceived rhythmic possibilities and their musical result, but also their physical sensation. By testing rhythmic ideas through singing, tapping, and playing, an understanding emerges that combines conceptual design, sonic outcome, and performance practicality. These factors compete, collaborate, and combine to inform my compositional decisions.

Throughout this dissertation, I approach speed as something listeners and performers construct through pulse following, subdivision, density, and attention. The felt sensations of audible rhythm are therefore inseparable from the ways bodies entrain to periodicities and imagine or simulate the actions that would produce them. In practice, the relationship of tuplets and groupings to the pulse provides a primary interface where such constructions of speed are negotiated.[28] This is a topic explicitly explored in my *Rhythmic Etudes* (2014), among other works.

While the implementation of tuplets and groupings in existing practices has created a seemingly infinite variety of rhythms, the exploration of pulse itself has often been limited. Most ensemble music assumes a single pulse for all musicians, which often remains relatively constant across a piece. This monotempo condition[29] functions as a strong organizing framework because it aligns bodily entrainment with a shared predictive timeline for "when" events should occur, and it reduces the cognitive and motor costs of maintaining coordination (Huron, 2006, p. 283).

Music with multiple pulses sounding simultaneously, first termed "poly-tempo" by Cowell (1928, pp. 26 - 27) and here referred to as polytempo, occurs far less frequently. The juxtaposition of different pulses for individual players, even when the speeds differ only slightly, introduces new performative challenges. In ensembles, there usually is a strong tendency to synchronize. A performer required to play at a different speed from a neighbor must actively resist these tendencies, which means managing embodied entrainment as well as competing streams of temporal prediction (Huron, 2006, pp. 175 - 177). Polytempo therefore multiplies speed references in the room and forces a redistribution of attention and effort. This redistribution is audible, since timing nuance is grounded in bodily action and mimetic imagery even for the listener (Iyer, 2002, pp. 394 - 403).

Perhaps because of challenges such as these, there have been only a few polytempo experiments in the past several centuries, which I explore below, and the results are rich, fascinating, and expressive. The approaches can be categorized by how they treat the elemental building blocks comprising the rhythmic grid: pulse, tuplet, and meter. While some of the approaches are instinctive and effortless, others demand considerable skill and concentration. This chapter will provide an overview of those approaches before dealing with my own research into polytempo. Its successful implementation has been a central goal in a series of my musical works, and I will detail both the process and the discoveries made through these experiments.

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[28] These are treated in more detail in Chapter 3: Tuplets.

[29] As defined by John Greschak in The Word "Polytempo", monotemporal music is music where "all parts are written with a common reference tempo and meter, and changes in tempo or meter occur in all parts simultaneously" (Greschak, 2007b).

Overview

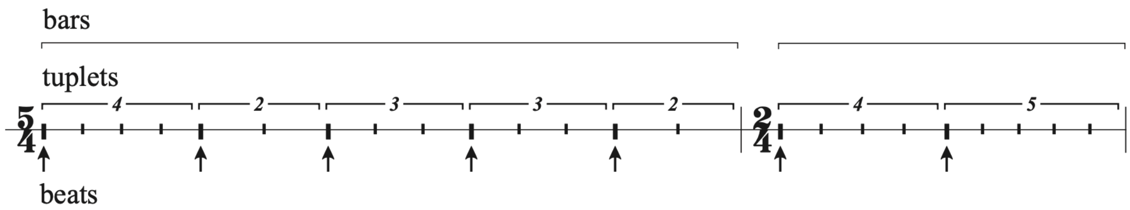
This chapter contextualizes polytempo from three perspectives and then presents the artistic and compositional research through which its design and realization are tested, showing how it offers a focused site for investigating speed as a relational phenomenon. I begin by contextualizing polytempo from three perspectives: within the identity and function of the rhythmic grid; as a theoretical permutation of the basic rhythmic elements of pulse, tuplet, and meter; and as a sonic condition encountered both in the everyday environment and in musical practice. I then turn to my artistic research through which I test these ideas, including a subsection on metronomes and on multiple sensory modalities.

Terminology

When referring to tempi in this chapter, I use both traditional Italian terms, such as *andante* (walking pace) or *vivace* (lively and fast), and numerical representations, such as 84 bpm. The terms convey the general qualitative character of a tempo (and thus the music), while the numerical values indicate exact tempi for quantitative comparison.

4.2 The Rhythmic Grid

Most Western music coordinates its various layers with a one-dimensional grid structure common to all musicians, showing the positions of the tuplets, beats,[30] and bars.[31]



Example 4.1: The Rhythmic Grid

The grid is a hierarchical structure, starting with elemental tuplet subdivisions within beats, which combine to form bars. Rhythms are lengths of sounds and silences placed within this structure. Although musicians often employ subtle rhythmic deviations for expressive purposes, this technical triumvirate plays a strong organizational role in both musical structure and performance practice. Crucially, this grid typically operates in monotemporal terms, maintaining a single tempo[32] for all beats.

The rhythmic grid not only structures monophonic music but also allows composers to align musical layers in time, and it enables ensembles of any size to synchronize performers.

Aside from the printed score, the grid can be presented in several ways, including:

- explicit articulation in the sounding music (by its notes)
- visual indication by a conductor or performer
- aural definition by a click track or metronome
- governance by the musicians' internal sense of the grid

In most performances, combinations of these presentations occur.

The internal grid of the performer plays a significant role in live performance. This grid rests on the musician's "inner pulse," providing the temporal framework for their actions. Arising from the musician's physical and cognitive experiences, it is inherently situated in Haraway's sense: embodied, partial, and produced from a particular position.[33] However, in ensemble contexts such as swing or groove, this internal sense of time must be actively negotiated among performers, becoming intersubjective. The way the grid is conceived, performed, and engaged with, reflects not only individual embodiment but also collective synchronization, influencing how the music is articulated (Grahn & McAuley, 2009).

Cognitive psychologist Daniel Levitin, neuroscientist Jessica Grahn, and music theorist Justin London note that the elements of the rhythmic grid are represented in the body as internal oscillators - biological clocks located in the brain and in various tissues and organs.

[30] Beat: the beat is a defined marker, often referring to the notated position.
[31] Bar: a segment of time containing a specific number of beats.
[32] Tempo is the speed of the beat in music, often measured in beats per minute (bpm).
[33] See section 2.5 for more about Haraway's theory.

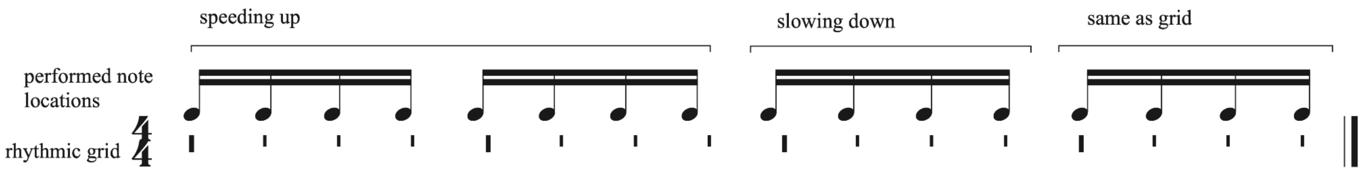
> Current models of rhythmic entrainment (Large & Kolen, 1994; Large & Palmer, 2002; Toiviainen & Snyder, 2003) posit that multiple internal oscillators phase lock to periodicities in a rhythm - most often to the beat, or tactus, but also to other levels of the metric hierarchy, such as the downbeats of successive measures. This phase locking is what allows a musician to keep track of multiple musical events simultaneously and to recover from errors while staying in time.
> (Levitin, Grahn, & London, 2018)

When two or more musicians perform together, their internal rhythmic grids must align to create a shared sense of timing. Although each musician has their own subjective grid, they must agree on a shared pulse, or underlying beat, which serves as the reference point for their collaborative performance. By paying attention to each other's playing, they can adjust these grids to match or complement their partner's timing, while still allowing for individual expressive timing.

Expression and the interaction of multiple rhythmic grids

While the rhythmic grid in Western notated music is typically expressed as whole numbers - such as the number of beats per bar and the number of subdivisions per beat, including tuplets - musicians frequently employ expressive timing,[34] introducing subtle deviations from this strict grid. These deviations include slight accelerations, decelerations or adjustments to note duration, often in the 20-100 ms range, thereby conveying excitement, calmness, phrasing emphasis, harmonic tension or other musical effects. Examples of expressive timing are notably found in swing, groove, and various non-Western musical traditions.

The following example shows a possible expressive timing, indicating the performed note positions in relation to the rhythmic grid.



Example 4.2. Expressive Timing

Music theorist Mitchell Ohriner expands upon the concept of expressive timing by identifying three types of interactions: between performer and musical object, between performer and performance tradition, and between collaborating musicians (Ohriner, 2019, p. 389). Building on my experience as a performer, I propose a further dimension to Ohriner's categories: the rhythmic grid itself constitutes a musical object with which performers dynamically interact during performance. This grid serves as the temporal frame of the music, requiring performers to maintain both cognitive and physical representations, an intellectual and embodied awareness of tuplets, beats, and bars. This practice may be common among musicians, since they are trained from early (often through counting exercises) on how the grid serves as the foundation for understanding and producing rhythm. However, certainly not every musician consciously thinks of the rhythmic grid at all times. With experience, many aspects of rhythm become intuitive. Nonetheless, during learning, practice or the performance of complex rhythms, the grid's divisions can be experienced as distinct musical events.

[34] As defined by Mitchell Ohriner, "'[e]xpressive timing' refers to variation in performed durations among notes represented in a musical score with a single rhythmic value" (Ohriner, 2019, p. 370).

Interaction with the grid becomes particularly dynamic during expressive timing, which is characterized by temporary deviations. In practice, I may adjust my internal grid to accommodate expressive timing, creating momentary expansions or contractions, or maintain the original grid positions, allowing expressive deviations to remain distinct. Expressive timing may also involve intentional tempo alterations of the grid itself, amplifying musical expressivity.

Expressive timing may thus be conceived as generating its own additional rhythmic grid. Performers therefore engage simultaneously with a *fundamental grid*, presenting the basic rhythmic structure, and an *expressive grid*, presenting interpretative deviations. These two grids may be merged into a single cohesive structure or kept distinct, resulting in multiple concurrent grids that one performer negotiates simultaneously.

In ensemble settings, this multiplicity of grids expands further. In a duo, for example, each performer's grids interact with those of their partner. When temporary rhythmic deviations occur, ensemble musicians have several interpretative options. Two musicians may have fundamentally synchronized grids but differ in their expressive deviations. At times, I might perceive my partner's acceleration as intentional and expressive. At other times, I may interpret it as unintentional rushing, just as they may perceive my steadiness as deliberate slowing down. The second musician can choose to align with these deviations, introduce independent expressive timings, or maintain a consistent grid. These dynamic interactions reveal communication, interpretative nuance, and musical choice.

Levitin, Grahn and London describe the management of these multiple grids through a hierarchy of internal oscillators:

> The hierarchical oscillators are even more important for musicians who want to play rubato or before or behind the beat - they need to know exactly when various levels of beat are being experienced (by themselves, by listeners, and by other ensemble players) in order to expressively alter their own timing. Musicians often use these techniques. Frank Sinatra famously sang behind the beat (giving the performance a cool quality), and Kendrick Lamar tends to sing ahead of the beat (giving the performance urgency). (Levitin, Grahn, and London, 2018, pp. 51-75)

This hierarchical model underscores the nuanced cognitive demands of expressive timing, emphasizing awareness not just of one's own internal grids but also of ensemble members' and listeners' rhythmic perceptions. In performance, similar techniques appear when soloists subtly rush ahead of the ensemble for expressive effect, highlighting virtuosity and excitement.

Recent research into sensorimotor alpha oscillations in the brain further clarifies how musicians interact with internal rhythmic grids, highlighting distinct cognitive strategies according to musical roles, such as playing in unison, canon or polyphonic textures (Christensen, Slavik, Nicol, & Loehr, 2023). As Christensen et al. explain, "leaders show greater reliance on internal models of action timing and increased activity in brain areas associated with internally driven motor processes such as action planning, initiation, and monitoring" (Christensen, Slavik, Nicol, & Loehr, 2023, p. 306). This observation echoes the discussion of interacting rhythmic grids, as it suggests that leadership in ensemble contexts draws heavily on an internally maintained temporal framework, one that must remain stable even while adapting to the real-time dynamics of other performers. It reinforces the idea that effective ensemble timing is not purely reactive but anchored in proactive, embodied control of the temporal structure. Later in this chapter, I explore how polytempo performance strategies leverage these cognitive processes according to the composition's structural characteristics.

Ultimately, the expressive potential of rhythmic timing in ensembles emerges from the interplay between multiple rhythmic grids. The manner in which these grids interact, synchronize, or intentionally diverge reveals performers' nuanced temporal sensitivities, creating diverse expressive possibilities aligned with the music's stylistic context.

As ensemble size grows, so does the complexity of rhythmic grid interactions, necessitating sophisticated coordination strategies. A professional string quartet musician, for example, continuously negotiates rhythmic relationships with the grids of their three colleagues. In larger ensembles, rhythmic coordination typically relies either on a central figure, such as a conductor, or on a network of mutual cueing among musicians. Such intricate interactions produce powerful expressive synchronizations, exemplified by symphony orchestras, and depend on the synchronization of both sight and hearing as well as the development of a common inner pulse (Lidar, 2016, pp. 5–8). The exploration and refinement of these modalities has been central to my approach to implementing polytempo music, as discussed later in this chapter.

4.3 Combinations of Rhythmic Elements For Possible Musics

Returning to the three parameters related to the rhythmic grid mentioned above, an examination of the implementation of pulse, tuplet, and meter offers a useful perspective for developing a typology of approaches to pulse-based music. Within these classifications, both existing (historical) examples of polytempo can be located, and possible avenues for further exploration identified.

Each parameter involves several variations, based on comparisons between layers in the music, for example between bass and treble parts, left and right hands on the piano, or two or more of any parts or players in the music.

- Pulses and tuplets can be the *same* or *different* between layers.
- Meters can be the *same*, *different* or *nonexistent*.

Pulse and tuplet are always relevant for this typology. Without pulse, there can be no polytempo. Moreover, when there is pulse, there is always some kind of tuplet, however many subdivisions it contains; even a beat without subdivision can be described as a tuplet of 1.

These options permutate into 12 possible combinations:

- 1.	same pulse	same tuplet	same meter
- 2.	same pulse	same tuplet	different meter
- 3.	same pulse	same tuplet	no meter
- 4.	same pulse	different tuplet	same meter
- 5.	same pulse	different tuplet	different meter
- 6.	same pulse	different tuplet	no meter
- 7.	different pulse	same tuplet	same meter
- 8.	different pulse	same tuplet	different meter
- 9.	different pulse	same tuplet	no meter
- 10.	different pulse	different tuplet	same meter
- 11.	different pulse	different tuplet	different meter
- 12.	different pulse	different tuplet	no meter

Only the latter six categories (those with a different pulse) qualify as polytempo. As will be shown in the examples below, monotempo approaches can still yield considerable rhythmic richness; however, this categorization helps illuminate explored and unexplored pathways, and provides context for the works presented here.

Below are one or more musical examples of each class, as utilized in at least one section of a work.

Category 1: same pulse - same tuplet - same meter

Igor Stravinsky, *Septet* (1953)

Most written music follows this combination. Quarter, eighth, and sixteenth notes all line up neatly within each beat and bar.

Example 4.3. Stravinsky, *Septet,* score excerpt. Video.

Category 2: same pulse - same tuplet - different meter

a. Antonin Reicha, *Fugue No. 30* (1803)

In the upper staff we see an 8/4 meter, with a 3/4 meter below beginning halfway through the first bar. This could be notated entirely in 8/4 (or cut time) with accents to mark the beginnings of each 3/4 bar. Single accented notes, however, do not capture the subtle hierarchies of stress and non-stress throughout whole bars.

Example 4.4. Reicha, *Fugue No. 30*, score excerpt. Video.

b. Johann Nepomuk Hummel, *Clarinet Quartet* (1808)

Here there are four simultaneous meters: 2/4, 12/8, 3/4, and 6/8. While the polymetric approach is clear, also in the musical phrasing, several aspects are less so, such as the reason for leaving out most barlines in the lowest line and the fact that the idiomatic writing in 3/4 could also have been represented in 9/8.

Example 4.5. Hummel, *Clarinet Quartet*, score excerpt. Video.

Category 3: same pulse - same tuplet - no meter

a. György Ligeti, *Etudes for piano: Étude 1, "Désordre"* (1985)

No meter is given. While all the eighth notes of both layers are in sync, the accents enable juxtaposed irregular groupings, which phase in relation to each other as the bottom-layer groupings periodically shift an eighth note.

Example 4.6. Ligeti, *"Désordre"*, score excerpt. Video.

b. Charles Ives, *Concord Sonata* (1840-60)

As in *Désordre* above, no meter is given and a common pulse unifies both layers. The barlines in this example function solely as structural markers for phrasing.

Example 4.7. Ives, *Concord Sonata*, score excerpt. Video.

Category 4: same pulse - different tuplet - same meter

Frédéric Chopin, *Trois Nouvelles Études* (1839)

An explicit example of triplets in the right hand against eighth notes in the left hand. From bar 9 each layer continues at its own speed.

Example 4.8. Chopin, *Trois Nouvelles Études*, score excerpt. Video.

Category 5: same pulse - different tuplet - different meter

A. Johannes Ciconia, *Le Ray au Soleyl* (est. 1390s)

A prolation canon[35] based on the ratios of speed 4:3:1. Here it is notated in the same meter for convenience, although the metrical identity of each layer would manifest in the length of each proportion.

Example 4.9. Ciconia, *Le Ray au Soleyl*, score excerpt. Video.

b. Giovanni Battista Vitali , *Balletto* (1689)

With the first violin in common time, the second violin in 12/8, and the violone in 3/4, this is a notational example of aligned beats with misaligned barlines.

Example 4.10. Battista Vitali, *Balletto*, score excerpt. Video.

[35]A prolation canon has the main melody accompanied by one or more imitations of that same melody in other voices, and at different speeds.

c. Wolfgang Amadeus Mozart, *Oboe Quartet* (1781)

Beginning in the sixth bar on the first line, the oboe switches to common time over continuing 6/8 in the strings. This is written as a meter change, although the result is a 4:3 relationship throughout the section, at various speeds: 2:3, 4:3, and 8:3.

Example 4.11. Mozart, *Oboe Quartet*, score excerpt. Video.

Category 6: same pulse - different tuplet - no meter

Kaikhosru Sorabji, *Transcendental Study no. 71* (1940-44)

Much of Sorabji's music is without meter, using dotted lines to indicate phrasing, similar to the phrasing barlines in Ives's *Concord Sonata*. The changing tuplets in both hands suggest an approach to notating rubato.

Example 4.12. Sorabji, *Transcendental Study no. 71*, score excerpt. Video.

Category 7: different pulse - same tuplet - same meter

a. Charles Ives, *The Unanswered Question* (1908, revised 1930-35)

Throughout this piece the flutes have recurring interjections that increase in speed with each iteration. According to the score, they need not be played at the exact notated position but "somewhat impromptu," following one of the flute players. The notation of different speeds defies the traditional convention of vertical alignment.

Example 4.13. Ives, *The Unanswered Question*, score excerpt. Video.

b. Witold Lutosławski, Symphony No. 2 (1965-67)

In this section the three flutes have the same metrical and melodic structure, in three different tempi and transpositions.

Example 4.14. Lutosławski, *Symphony No. 2*, score excerpt.

Category 8: different pulse - same tuplet - different meter

a. Charles Ives, *Central Park in the Dark* (1906, revised 1936)

One of the earliest polytempo compositions, if not the earliest. Polytempo is achieved by specifying one layer to change meter and speed up while the other remains at Tempo I. How this is achieved, for example with two conductors or with individual leaders for each of the two separate layers, is not specified.

Example 4.15. Ives, *Central Park in the Dark*, score excerpt. Video.

b. Carl Nielsen, *5th Symphony* (1920-2)

In this other early polytempo example, Nielsen uses a metronome to give the snare drum its own tempo, without barlines to avoid alignment with the rest of the orchestra.

Example 4.16. Nielsen, *5th Symphony*, score excerpt. Video.

Category 9: different pulse - same tuplet - no meter

Building Music (McGowan, 2013)

Each musician has their own tempo of repeated notes and non-metric texture. Explored in more depth below, the notated barlines function not in the traditional sense of meter, but to delineate harmonic changes.

Example 4.17. *Building Music*, score excerpt. Video.

Category 10: different pulse - different tuplet - same meter

Charles Ives, *The Unanswered Question* (1930-35)

In another section of this work (also used in Category 7), the range of speed is broadened not only by shifts in tempo but also by variations in tuplets, which here introduce the distinctive character of triplets.

Example 4.18. Ives, *The Unanswered Question*, score excerpt. Video.

Category 11: different pulse - different tuplet - different meter

Elliott Carter, *String Quartet No. 3* (1973)

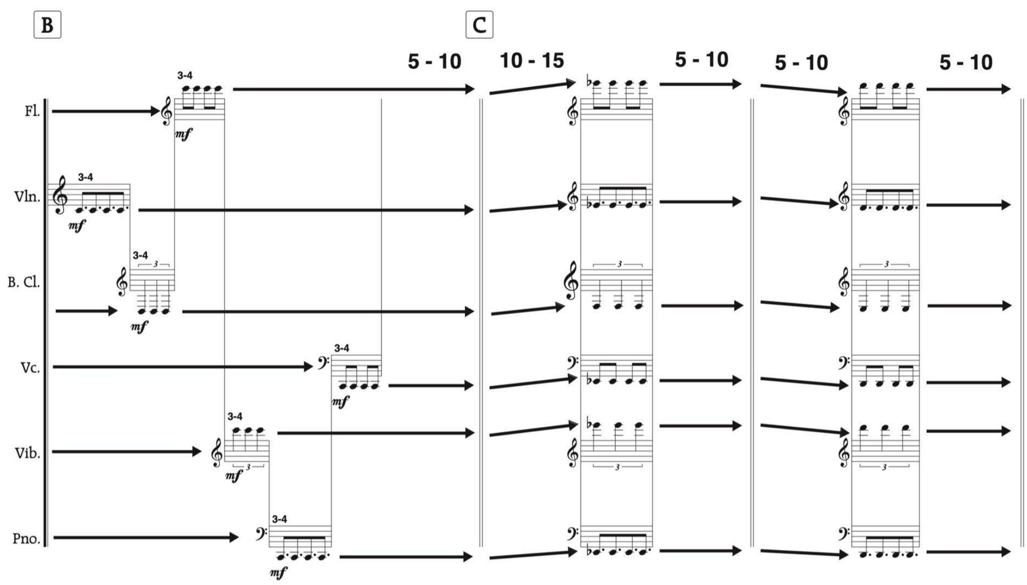
The four players are divided into two duos, each with its own tempo and meter. Within each duo the materials often employ different tuplets. The tempi are related so that the beginnings of each bar coincide.

Example 4.19. Carter, *String Quartet No. 3*, score excerpt. Video.

Category 12: different pulse - different tuplet - no meter

Sydney Polypulse (McGowan, 2019)

Explored in more depth below, the speed of each player's repeated notes is determined by the combination of their own tempo and tuplet. As in *Building Music* above, repeated notes erase metrical identity.



Example 4.20. *Sydney Polypulse*, score excerpt. Video.

Reflections

This categorization has proven fruitful for understanding how the building blocks of the rhythmic system create pathways for mixing speeds in music.

In the first six categories, the pulse plays a consistent role. On this foundation, the differences and boundaries between tuplet and meter are explored. The difference between the two appears primarily one of scale: the ways in which tuplets are juxtaposed (as in Chopin and Mozart) are similar to the ways in which meters are juxtaposed (as in Reicha). Tuplet duration is related to single beats, whereas meters relate to multiple beats. This mirrors the different scales of speed in the Beethoven examples: when tuplets are slowed down, they become meters, allowing other details to emerge.

The polytempo works of the latter six categories can be divided into two main approaches. The first comprises works that create distinctly different temporalities through layering, as in Ives and Nielsen. These layers possess their own musical identities, characterized by elements such as melody, harmony, rhythm, and timbre, and are further differentiated by speed. The second approach encompasses works in which a direct juxtaposition of different speeds fosters a new, singular, composite sound, as in Carter's quartet and my own compositions. While these works also aggregate individual parts to form a cohesive whole, the parts are more uniform in material content and more closely synchronized in phrasing and points of intersection. Much of the musical content emerges from the explicit interactions between the layers.

4.4 Polytempo Music

Before outlining various approaches to polytempo music, it is useful to consider some familiar examples from everyday life.

Unsynchronized sound in nature

Unsynchronized sound is common in our daily environment. A walk through a city, for example, presents a constantly shifting mix of uncoordinated sounds from vehicles, machinery, weather, birds, and human activity. Such experiences can inspire musical ideas, offering examples of layered rhythms and tempi found outside composed contexts. These may combine regular, irregular, and singularly occurring sounds.

- Animal sounds
  Example 4.21. *Cacophony of animal sounds in our yard*, video.

- City sounds
  Example 4.22. *Vehicle Noise in Dhaka Street*, video.

- Hospital machine sounds
  Example 4.23. *HP Viridia 24 ECG/Resp, SpO2 Alarms*, video.

Composed polytempo music

Music in which two or more different tempi occur simultaneously can be roughly divided into two categories (Greschak, 2007a):

- *Static polytemporality*: two or more simultaneous tempi that remain constant.

- *Dynamic polytemporality*: at least one of the simultaneous tempi changes over time (Mikolajczyk, 2019, p. 16).

Here are some examples of each category to give an idea.

Static polytemporality:

- Conlon Nancarrow, *Study No. 9* (1951 - 1960), for player piano

  The groundbreaking *Studies for Player Piano* explored a wide range of approaches to multiple simultaneous speeds. In *Study No. 9* the three layers are in tempi to the proportions of 3, 4 and 5, and at 1′30″ the music demonstrates the polytemporal quality where each layer inhabits its own rhythmic grid of speed. According to composer-scholar Kyle Gann:

  > It is almost as though Nancarrow is imagining three continuously running stereo type tape loops that he can bring in one track at a time via a mixer, with the additional luxury of being able to change speeds. (Gann, 1985, p. 82)

  Example 4.24. Nancarrow, *Study No. 9*, video.

- *Hydraulic Principles* (McGowan, 2012), for player piano

    To give a reference to Nancarrow's approach to polytemporality, *Hydraulic Principles* is a work, also for player piano, that is monotemporal; all of the layers during the climax (5:00) relate to the same underlying pulse.

    Example 4.25. *Hydraulic Principles*, video.

- György Ligeti, *Poème Symphonique* (1962), for 100 metronomes

    The metronomes, all set to different tempi, start at the same time and are left to wind down at their own speed. At first the resulting sound is a blizzard of clicks, but as metronomes fall out, individual voices begin to emerge, revealing interesting phasing patterns.

    Example 4.26. Ligeti, *Poème Symphonique*, video.

- Michael Gordon, *Trance* (1995), for large ensemble

    The sound of "Part 1" of *Trance* reveals three clear independent musical lines, each with its own strong pulse, yet notated to a single rhythmic grid.

    Example 4.27. Gordon, *Trance*, audio.

- Marc Sinan, *AM ANFANG* (2020), for Djiguiya Orchestra Bamako, the Marc Sinan Company, the Neue Vocalsolisten Stuttgart, choreographer Kettly Noël and video

    In order to create independence and separation between the five groups, each is given its own tempo via click tracks, synchronized by a single computer.

    Example 4.28. Sinan, *AM ANFANG*, video.

- Christina Kubisch, *Identikit* (1974), for five pianists, cassettes and headphones

    This work utilizes polytemporality in a similar manner to Ligeti's *Poeme Symphonique*, with strings of notes in a constant speed from each player on the piano.

    Example 4.29. Kubisch, *Identikit*, audio.

Dynamic polytemporality:

- Conlon Nancarrow, *Study No. 21, "Canon X"* (1961), for player piano

    Each of the two layers in the music, one fast, one slow, perform a continuous speed change to transform into the other.

    Example 4.30. Nancarrow, *Study No. 21*, video.

- Yannis Kyriakides, *Wavespace* (2011), for mixed octet, live electronics and live video

    (excerpt beginning at 06:23) The passage from the excerpt combines layers of different temporalities: a regular pulse, one speeding up, one slowing down, and several others which are irregular.

    Example 4.31. Kyriakides, *Wavespace*, audio.

- Florent Ghys, *Il va pleuvoir en fin d'après-midi* (2018), for ensemble

  The basic syntax is similar to *Building Music* with the use of layers of repeated notes at different speeds. Similar to *Wavespace*, this piece uses click tracks to cue individual musicians to gradually speed up and slow down throughout the work, increasing or slowing down the phasing duration.

  Example 4.32. Ghys, *Il va pleuvoir en fin d'après-midi*, video.

- Ned McGowan, *Telescopic Ladder* (2003) (from *Tools)*, for mixed quartet

  This passage represents an early exploration of the polytempo effect, realised through structured improvisation. The classification is somewhere in between static and dynamic polytemporality, as static speeds are switching constantly in the various parts, plus an additional accelerando at the end.

  Example 4.33. *Telescopic Ladder,* video.

4.5 My Polytempo Works

4.5.1 General aesthetic and technical setup of my polytempo music

The approach to the polytempo technique I used in the works below employs static polytemporality, where each instrumental part consists of repeated notes, each at its own speed.

- *Building Music* (2013)
    for solo voice, large wind ensemble of 24 instrumentalists (flute, oboe, clarinet, bassoon, soprano, alto, tenor, baritone and bass saxophones, 2 piccolo trumpets, 2 trumpets, cornet, 4 trombones, bass trombone, tuba, guitar, bass, and 2 percussion) and video

- *For Bob* (2015)
    for large ensemble and solo voice
    composed for the posthumous birthday of musicologist Bob Gilmore
    In what follows four different performances of *For Bob* are considered.

    version 1: mixed instruments
        2 flutes, 2 violins, 2 violas, piano 4 hands and 2 vocalists, myself conducting
    version 2: flutes
        7 flutes, alto flute, bass flute and contrabass flute
    version 3: Jerboah
        2 recorders, Paetzold bass recorder, contrabass flute, guitar, glockenspiel and voice (ensemble Jerboah)
    version 4: Fokker Organ
        flute/contrabass flute and Fokker Organ (with parts triggered via MIDI and parts played live)

- *Sydney Polypulse (2018)*
    for flute, clarinet, violin, cello, piano and vibraphone

In these pieces, all voices are intended to have equal prominence, creating a "cloud" of simultaneous speeds. This equality contrasts with the typical hierarchical approach that places some layers in the foreground and others in the background. The similarity of material across the repeated note texture unifies the sound, while each player remains distinct through their unique speed, timbre, and often pitch. Each voice functions as both a soloist and part of the whole. Within this equality of prominence, the individuality of each voice still enables connections between any two speeds, ranging from close to far apart. Phase effects emerge as repeated notes align, drift, and realign. In this setup, each line of repeated notes at a fixed speed is straightforward to execute, while the richness comes from the interplay between speeds. Layers of simplicity combine into a multifaceted web of fixed tempo relationships, producing a structured and resonant sound. That said, maintaining one's tempo remains a challenge for performers, a subject explored later in this chapter.

4.5.2 Entrainment and polytempo performance difficulties

As mentioned above, musicians readily coordinate when playing notated music by articulating from a shared, monotemporal rhythmic grid. Within entrainment theory, this kind of coordination is described as the interaction of two or more autonomous rhythmic processes that adjust and eventually "lock in" to a common phase or period (Clayton, Sager & Will, 2005, pp. 1–3). In ensemble performance this synchronization depends on a complex interplay of perceptual, cognitive, and motor processes that underlie what is often called sensorimotor synchronization, the rhythmic coupling of movement to an external sequence (Repp & Su, 2013, p. 403). One influential account of ensemble synchronization emphasizes that such coordination presupposes shared performance goals and relies on skills such as anticipatory auditory imagery, prioritized integrative attention, and adaptive timing, all of which link internal timing mechanisms to real-time motor control (Keller, 2007). Empirical studies of duet performances further show that auditory feedback, visual cues, rehearsal, familiarity with co-performers, and shared stylistic understanding all contribute measurably to the precision with which musicians stay together in time (Goebl & Palmer, 2009, pp. 427-428).

The tendency to synchronize rhythm is not only a learned musical skill but also a general feature of human interaction. Entrainment research frames it as a widespread property of biological and social systems in which rhythmic processes tend to adjust to one another, from the synchronised flashing observed in some firefly populations, through the temporal coordination of conversational speech, to coordinated bodily movement such as walking, clapping, or dance (Clayton et al., 2005, pp. 2–3). In cognitive terms, this involves automatic alignment processes and predictive timing abilities that support the joint action of adaptive error-correction and anticipatory internal models in sensorimotor synchronization (van der Steen & Keller, 2013, p. 2). Laboratory work on tapping tasks indicates that phase-correction mechanisms operate largely automatically, while slower period-correction processes require conscious attention (Repp, 2005; Keller, 2007), and that in-phase coordination is much more stable than antiphase or syncopated coordination (Keller & Repp, 2005). Musicians therefore not only anticipate upcoming events once entrained but also experience a strong attractor towards synchrony, a "gravitational pull" that makes it cognitively and motorically difficult to remain deliberately out of time. As I will argue below, this attractor becomes particularly resistant in polytempo contexts, where the maintenance of distinct tempo layers requires performers to counteract precisely the mechanisms that normally make ensemble playing feel intuitive.

The strength of this pull often goes unnoticed until one deliberately tries not to synchronize. Even a small difference in tempo, such as 124 and 120 bpm occurring simultaneously, demands considerable effort to maintain: the ratio of 31:30 is so close that performers are continually drawn into alignment. By contrast, combinations such as 120 with 60 or 40 bpm, whose ratios are much simpler and more widely separated, are relatively easy to sustain as distinct layers. In the polytempo music described here, these finely graded tempo relationships are not incidental details but central to the music's identity.

Example 4.34. [124 and 120 bpm](), audio.

For this reason, all of my polytempo works require each musician to use a metronome set to their own tempo. In theory, this provides a personal rhythmic grid that stabilizes each player's tempo and allows the ensemble's layered tempi to emerge clearly. In practice, however, resisting the surrounding players' timing remains challenging. Even with precise metronomic guidance, musicians must consciously focus on their own grid and suppress the natural urge to align with nearby sounds. This skill develops through targeted practice, and in the following section I outline strategies for cultivating it.

4.5.3 Polytempo research in my works

From here, the chapter examines five practice-centered problems that recur in my polytempo work: selecting tempi, implementing note values, using metronomes, coordinating musicians, and developing performance practice. Rather than presenting the three works separately, the chapter uses *Building Music* (2013), *For Bob* (2015), and *Sydney Polypulse*(2018) as recurring case studies within each problem-oriented section. This organisation foregrounds process and iteration: work titles function as local labels for the example at hand, not as a return to a work-by-work narrative.

4.5.4 Choosing the tempi: ratios and ranges

In static polytempo ensemble music where each musician maintains an independent tempo, a primary compositional consideration is the choice of tempi. Unlike in monotemporal works, tempo must be decided for each independent tempo layer, which may be assigned to a single musician or shared by several, making the selection process inherently more complex. Determining these tempi, and understanding their interrelationships, can thus constitute a distinct and often timeintensive phase of the compositional process.

This section first outlines tempo-selection approaches found in representative polytempo works by other composers, and then presents a detailed account of my own research, decisions, and outcomes. Dynamic polytempo works, which employ techniques such as acceleration, deceleration, tempo curves, and technology assisted modulation, are excluded here because their continuous tempo modulation and frequent reliance on technological mediation raise different compositional and performative questions than the globally static tempo layers examined in this chapter. As composer Marc Kenneth Yeats argues in his thesis, “Control, Flexibility, Flux and Complexity: A Timecode-Supported Approach to Polytemporal Orchestral Composition”(2021, pp. 33–72), many dynamic or large scale polytempo works presuppose a substantial technical infrastructure, for example computer controlled click tracks, systems with multiple or video conductors, networked video scores on iPads, mobile phone timecode and stopwatch frameworks, or headphone and app based guides. This creates a very different performance ecology from the one I address. By contrast, the works discussed in this chapter rely on ubiquitous electronic or digital metronomes that provide a single tempo for the entire piece, and explore strategies of notation that generate internal dynamism while remaining within a globally static polytempo field.

Tempi in ratios

Two primary approaches to tempo selection parallel two common approaches to pitch relationships: one uses simple ratio-based systems, akin to scales formed from whole-number ratios as in just intonation, and the other employs systems where a chosen range is divided into equal intervals, akin to the 12-tone equal-tempered scale. Both approaches appear in the *tempo-scale* theories devised by Henry Cowell and Karlheinz Stockhausen.

A tempo scale lists tempi that correspond to the degrees of a musical scale. Each “note” of the scale has a corresponding tempo, and interrelationships between tempi correspond to those between pitches. Both Cowell and Stockhausen illustrate this concept with chromatic scales, assigning the lowest pitch a tempo of 60 bpm and the octave above 120 bpm. The underlying assumption is that the doubling of pitch frequency over an octave corresponds to a doubling of tempo, as both relationships form a 2:1 ratio.

In *New Musical Resources*, Cowell applies simple ratios derived from just intonation to both pitch and tempo, proposing that relationships among tempi can be treated analogously to relationships among pitches (Cowell, 1930, p. 107). Elliott Carter takes up this idea in his use of metric modulation, which is described more precisely here as speed modulation, and he treats it as a counterpart to harmonic modulation for articulating musical form (Bernard, 1988, p. 199). The *Double Concerto* (1961) brings this line of thinking to a particularly systematic point, since simultaneous speeds become a normative condition of the piece. Carter draws on a unified set of ratios, from 5 to 10 and their reciprocals, to derive ten distinct tempi, including a 49:50 relation between 24.5 and 25 bpm. Each tempo is paired with a specific interval, so that rhythmic and pitch relations are coordinated as one structural dimension (Bernard, 1988, pp. 188–189).

Stockhausen, in his article "...how time passes…" , applied the 12-tone principle of equality to the same octave distance as Cowell, creating the equivalent of an equal tempered chromatic scale by dividing the octave into twelve equal steps (each related by the ratio $\sqrt[12]{2}$ to 1) (Stockhausen, 1957/1959, p. 21). In *Gruppen*, his polytempo work for three orchestras, the ensembles regularly shift between tempi on this scale, creating "harmonic" tempo relationships comparable to Carter's approach. Stockhausen later drew on the same chromatic tempo scale in other pieces: in *Inori* (1973–1974), for example, successions of tempi function as "tempo-melodies" that articulate large-scale formal processes.

Pitch	ratio Cowell	**bpm Cowell**	**bpm Stockhausen**	(& rounded values used in *Gruppen*)
- C	1:1	**60**	**60**	(60)
- C#	15:14	**64 $\frac{2}{7}$ (64.3)**	**63.6**	(63.5)
- D	9:8	**67 $\frac{1}{2}$ (67.5)**	**67.4**	(67)
- Eb	6:5	**72**	**71.4**	(71)
- E	5:4	**75**	**75.6**	(75.5)
- F	4:3	**80**	**80.1**	(80)
- Gb	7:5	**84**	**84.9**	(85)
- G	3:2	**90**	**89.9**	(90)
- Ab	8:5	**96**	**95.2**	(95)
- A	5:3	**100**	**100.9**	(101)
- Bb	7:4	**105**	**106.9**	(107)
- B	15:8	**112 $\frac{1}{2}$**	**113.3**	(113.5)
- C	2:1	**120**	**120**	(120)

Figure 4.1: One octave tempo scales of Henry Cowell and Karlheinz Stockhausen

A comparison of these scales shows that the results are similar but not identical, reflecting the subtle differences between just intonation and equal temperament. Psychophysical studies suggest that we can detect much smaller changes in pitch than in the length of time intervals. Just-noticeable differences[36] in frequency are roughly an order of magnitude smaller than just-noticeable differences in duration, and this asymmetry is reflected in both musical tuning practice and the fine-grained use of pitch in speech prosody. In *Gruppen*, Stockhausen rounded most decimal values to whole numbers in rehearsal practice, since

[36] Psychophysical studies usually describe such "micro-differences" in terms of just noticeable differences (JNDs), the smallest change that can be detected reliably. For steady pure tones in the mid-frequency range (roughly 500–2000 Hz), frequency JNDs for normal-hearing listeners are typically well below 1% of the base frequency (Moore, 2012, pp. 205-7). By contrast, duration-discrimination experiments in the range of a few hundred milliseconds to a few seconds usually report By contrast, duration-discrimination experiments in the range of a few hundred milliseconds to a few seconds usually report Weber fractions, meaning the proportional change in duration ($\Delta t/t$) needed for reliable discrimination, typically on the order of 5% or more (Grondin, 2010, pp. 564, 582). In practical terms, listeners resolve smaller proportional differences in pitch height than in temporal interval length, a fact exploited both in musical tuning practice and in the fine-grained pitch movements that carry speech prosody (Patel, 2017, pp. 185-216).

standard mechanical metronomes of the period offered only a discrete series of integer tempo markings rather than continuously adjustable or decimal BPM settings.[37]

Conlon Nancarrow also worked extensively with tempo ratios in his *Studies for Player Piano*, though primarily focusing on a single relationship between two tempi rather than generating a complete scale. Examples include the following pieces (Thomas, 2000, p. 137):

- *Study No. 15* – 3:4 ratio (165 and 220 bpm)
- *Study No. 17* – 12:15:20 ratio (138, 172.5, and 230 bpm)
- *Study No. 33* – √2:2 ratio (198 and 280 bpm)
- *Study No. 40* – *e:π* ratio (tempi not specified)

In a different but related vein, Richard Barrett develops what he calls "rhythmic subdivisional grids," in which families of tempi are derived from multiplicative ratios around a chosen basic pulse rather than from a fixed global tempo scale (Barrett, 2019, pp. 18–20). In the non-hierarchical version of this system, he specifies a set of speeds that are "as far as possible all equally distinct from one another", which leads him to construct a logarithmic scale of tempo multipliers between 0.75 and 1.5 of a unit value. These multipliers are then applied to a given duration and approximated by small integer ratios (for example 12:16, 13:16, … 24:16), producing a grid of related but non-coinciding subdivision speeds that can be permuted across parts to create a finely graded rhythmic heterophony. In the complementary "harmonic" or hierarchical version, Barrett follows Clarence Barlow in ranking subdivision ratios by a kind of rhythmic harmonicity coefficient, so that simple ratios articulate an underlying pulse while more complex ones are perceived as tempo variations. Compared with Cowell's just intonation tempo scales and Stockhausen's equal tempered chromatic scale of tempi, Barrett's practice is less concerned with mapping tempo directly onto pitch systems and more with generating a continuum between coordinated and discoordinated activity across multiple layers. His logarithmic spacing and probabilistic use of ratios serve to regulate the density, distinctness, and degree of synchronization between simultaneous streams, rather than to produce "tempo harmonies" or modulatory trajectories in the sense found in Cowell, Carter or Stockhausen.

In another, more directly proportional application of ratio-related tempi, composer and guitarist Marc Sinan in *At First* creates five sections of music with durations in the proportions 5:4:3:2:1 and assigns tempi in inverse proportion. Beginning with a maximum of 180 bpm, he derived the other tempi as 36, 72, 108, 144, and 180 bpm. The choice of 180 bpm was based on his estimate of a practical performance limit for music using sixteenth notes (personal communication, 2 November 2022), a principle I also applied in *Building Music*, discussed below.

Ranges of Tempi

Another approach to choosing tempi is to create a list from slowest to fastest, without reference to a repeating scale at the octave. For example, in Ligeti's *Poème Symphonique*, he specifies a range between 50 and 144 bpm, distributed among the 100 metronomes. This approach depends on two main factors: the upper and lower limits, and the distribution of tempi within that range.

In the score, each metronome is to be wound exactly four times, meaning that faster metronomes stop sooner than slower ones. Ligeti describes the result as "a single long phrase which could be characterized as a rhythmic diminuendo" (Ligeti, 1962, p. 5). In the final minutes, only a few metronomes remain,

[37] Standard Maelzel-type mechanical metronomes provide a fixed, non-linear series of integer BPM markings, typically from 40 to 208, in steps such as 40–42–44 … 200–208; only later digital and software metronomes allow finer-grained or "virtually continuous" tempo adjustment, including arbitrary intermediate values and decimals.

producing a single sparse yet clearly polytemporal texture. While any metronome range from 40 to 208 bpm would create the diminuendo effect, the combination of winding limitations and the desired overall duration - 15 to 20 minutes according to the score - likely informed Ligeti's choice of 50–144 bpm.

Regarding distribution, the mechanical metronomes available at the time (and specified in the score) offered the following discrete tempi: 50, 52, 54, 56, 58, 60, 63, 66, 69, 72, 76, 80, 84, 88, 92, 96, 100, 104, 108, 112, 116, 120, 126, 132, 138, and 144 bpm. This excluded both decimal tempi and many specific non-decimal values such as 51, 62, or 124 bpm.

My own approach in the three polytempo compositions discussed below also uses tempo ranges. However, unlike the closed tempo scales derived from pitch relations in Cowell and Stockhausen, or the graded grids of subdivision ratios developed by Barlow and Barrett, the tempi in my works emerge from a set of practical and perceptual constraints: performance limits, metronome availability, and the registral distribution of the ensemble. Several additional guidelines shape these choices, as will be explored in the following section.

In my first polytempo work, *Building Music,* the tempi were not drawn from a pre-existing tempo scale or subdivisional grid, but were chosen according to four guidelines.

Firstly, to impart vitality to the mixture of pulses, I set a brisk walking pace (andantino) of roughly 80 bpm as the lower limit. The upper limit is 160 bpm, aligned with the maximum practical speed for continuous articulated sixteenth notes that appear in the final section. Unlike Sinan's choice of 180 bpm in *At First*, I prefer the slightly slower 160 bpm. This preference originates in my college practice routines, where I used the long strings of articulated sixteenth notes in J. S. Bach's *Sonata in C Major* (BWV 1033) as articulation studies, and where my teacher, flutist Jeffrey Khaner, treated 160 bpm as the technical ceiling.

Second is the question of how to distribute the tempi. Given a spread between 80 to 160 bpm, a first approach might be simply to divide that range by the number of instruments, and then space them evenly throughout. 80 bpm range / 25 musicians[38] = 3.2 bpm tempo difference between each instrument, e.g. 160, 156.8, 153.6, etc… However, there are two problems with this approach. First, the possibility for setting tempi based on decimal divisions is not very common on metronomes (still in the twenty-first century), presenting a practical issue. Second, Weber's law of *just-noticeable difference*[39] specifies that perceived tempo change is proportional between two tempi, meaning that a difference of 3 bpm, for example between 80 and 83 bpm, is perceived to be greater than the 3 bpm difference between 157 and 160 bpm.[40] In order to compensate for this effect within the 80 - 160 bpm range, and also to avoid decimal tempi, I created speed differences of 2 bpm in the slower tempi, 3 in the medium tempi and 4 in the faster tempi.

The third guideline mapped slower tempi to lower-pitched instruments and faster tempi to higher-pitched instruments. This approach was intended to enhance the clarity of the polytempo texture. Traditionally, lower voices in harmonic textures articulate slower, more sustained patterns, while higher melodic voices tend to move faster and with greater surface detail, a division of labor that is consistent with findings that bass-range sounds provide a more accurate temporal reference while higher-pitched voices are perceptually

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[38] The vocalist was included in this calculation.
[39] Mahr and Cheprasov, (2022) What is Weber's Law?
[40] This effect is compensated for in the tempi scaling on traditional metronomes: it changes in increments of 2 bpm from 40 to 60, increments of 3 between 60 and 72, increments of 4 between 72 and 120, increments of 6 between 120 and 160 and increments of 8 bpm from 160 to 208. The percentage of change ranges from 3.33% to 5,26%. From 120 until 208 can be seen as a doubling of the tempos from 60 onwards.

dominant carriers of melodic information (Hove, Marie, Bruce, & Trainor, 2014; Trainor, Marie, Bruce, & Bidelman, 2014).[41]

This mapping resulted in clusters of close tempi within each octave of the ensemble's range.

Tempi of the instrumentalists of *Building Music*, in bpm:

- 160 - piccolo trumpet 1
- 156 - alto saxophone
- 152 - oboe
- 148 - piccolo trumpet 2
- 144 - flute
- 140 - cornet
- 136 - trumpet 1
- 132 - percussion 1
- 128 - voice
- 125 - electric guitar
- 122 - trumpet 2
- 119 - trombone 4
- 116 - soprano saxophone
- 113 - piano
- 110 - tenor saxophone
- 107 - trombone 3
- 104 - bassoon
- 101 - bass trombone
- 98 - trombone 2
- 96- acoustic bass
- 94 - baritone saxophone
- 92 - trombone 1
- 90 - percussion 2
- 88 - bass saxophone
- 86 - tuba

For the fourth guideline, I avoided assigning tempi very close in value, to physically adjacent musicians, in order to minimize the natural synchronization effect between neighbors. Ensembles tend to set up their stage positions by grouping families of instruments together. This can create situations in which the third and fourth guidelines directly conflict, for example when all trumpets are seated next to one another and their tempi are close in value. The solution was to separate the closest tempi from each other. The 1st trumpet is assigned a speed of 136 bpm, the cornet with a speed of 140 bpm, and they are physically separated by the 2nd trumpet at 122 bpm.

[41] It could be interesting, however, to invert this situation, or explore other relationships between tessitura and range.

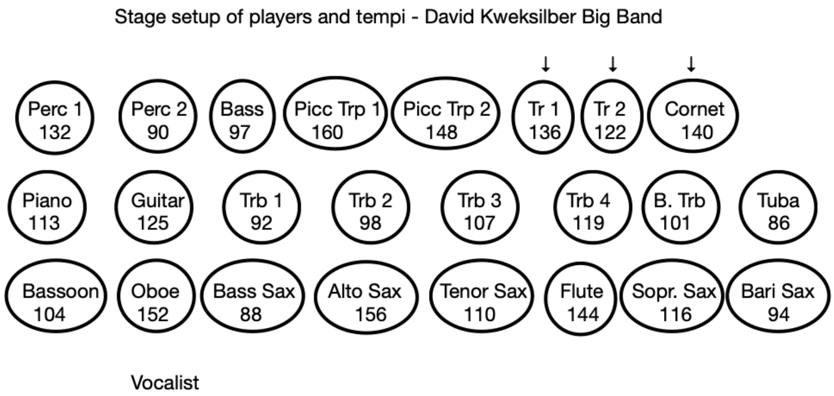

Figure 4.2: Stage setup of players and tempi

Ligeti's *Poème Symphonique* offers an interesting point of comparison: the slower metronomes are placed at the front of the stage and the faster ones at the back, presumably so that the slower, still-running metronomes at the piece's end are closest to the audience. This allows the public to hear the rich interactions between the remaining speeds at close range. Similarly, Sinan's *At First* positions its five tempo groups around the audience, creating a spatialized listening experience. Such spatialization of different tempi is a recurring theme in many polytempo works.

The combined result of all these tempo-selection processes can be heard in the following video excerpt:

Example 4.35. *Building Music*, video excerpt.

The intention for the polytempo work, *For Bob*, was to create a piece commemorating a dear friend who had passed, and I set out to see if I could use the polytempo technique to create a slower, more reflective piece. In contrast to *Building Music*, with its tempi ranging from 86 to 160 bpm, *For Bob* employs a narrower and slower range of 75 to 115 bpm. This restricted tempo span, combined with longer note values such as dotted half notes and half notes, produces a subdued and meditative quality, quite unlike the active pulsing of *Building Music*. Throughout the various arrangements of this piece, distributions of tempi between the instruments were determined by simply dividing the total range (40 bpm) by the number of instruments, and assigning each player one of the divisions. The tempo distribution of Version 1 of *For Bob* has been lost so I will detail versions 2 and 3 here.

Version 2: flutes

- 75 - flute 6
- 80 - flute 5
- 85 - contrabass flute
- 90 - flute 4
- 95 - bass flute
- 100 - flute 3
- 105 - alto flute
- 110 - flute 2
- 115 - flute 1

Example 4.36. *For Bob*, video.

Version 3: Jerboah

- 75 - contrabass recorder
- 83 - contrabass flute
- 91 - alto recorder
- 99 - electric guitar
- 107 - glockenspiel
- 115 - recorder

Example 4.37. *For Bob*, audio.

In both versions listed here, the instruments are separated by equal speed increments - 5 bpm in the flute version and 8 bpm in the Jerboah version. Since the total range of 40 bpm is considerably narrower than the 74 bpm span in *Building Music*, the proportional difference between the slowest and fastest instruments is relatively small. As a result, the exact increment size does not significantly alter the perceptual separation between tempi.

As in *Building Music* and *For Bob,* each instrument is given its own tempo, but to create *Sydney Polypulse* I conducted more thorough research into the possibilities for tempo combinations between the instruments. One consequence of two instruments repeating notes at different speeds, for example 70 and 80 bpm, is a clearly audible phasing effect.

Example 4.38. violin, 70 bpm; flute, 80 bpm, audio.

Phasing in music, as I use the term here, is a compositional technique in which the same phrase, or even a single repeated note as in some of my examples, is performed by two or more voices at slightly different tempi, so that their points of coincidence gradually change. Related ideas already appeared in medieval and Renaissance mensuration canons and isorhythmic motets, where voices proceeded at proportional speeds and slowly drift out of alignment, although in those repertories the effect was embedded in contrapuntal practice rather than presented as a foreground process. In 20th-century usage the term phasing usually refers to the technique pioneered by Steve Reich, who made the gradual change of phase itself the principal object of perception. This can occur either when two voices begin at different points but repeat with the same tempo, so that the phase difference remains constant and the result resembles an echo, or when one of the voices adopts a slightly different tempo so that the phase difference is continually transformed. In *Drumming* (1971), for percussion ensemble, Reich combines these approaches: a rhythm is first repeated in unison, then one performer marginally increases tempo until the pattern is displaced by one unit against the other part, at which point this new alignment is stabilized before a further phase shifting process begins.

Example 4.39. Reich, *Drumming*, video.

How close do two tempi need to be before their combination gives rise to a perception of phasing? Psychophysical studies on tempo discrimination suggest that listeners begin to notice a change of tempo at around four to five percent of the base tempo. Below that threshold the difference is often imperceptible in typical listening conditions, whereas above it the two streams are more readily heard as moving at different speeds rather than as a single, slowly shifting pattern (Quené, 2007, pp. 135, 183; McAuley, 2010, p. 140). Reich’s style phasing tends to occupy this narrow band. The tempo difference is large enough for the alignment between patterns to drift audibly over the course of many repetitions, yet small enough so that locally the parts still fuse into a single pulse rather than separating into two clearly distinct meters. In what follows I refer to this narrow band of tempo differences as the *phasing region*.

In all of my polytempo works where musicians follow metronomes, the parts are never in unison for more than one iteration, because the tempo differences between parts place them within this phasing region and create a constant slow shifting of alignment. Speed differences in simple ratios such as 2:1 or 3:2 also involve simultaneous but different speeds, yet they do not produce the same perceptual effect. In those cases the streams are usually heard as two distinct rhythmic layers or as a proportional canon, rather than as one pattern gliding past another. In example 4.38 above the flute plays slightly faster than the violin. The two parts begin synchronized, gradually separate and eventually return to synchronization, at which point the process can begin again. Below, in section 5.5.3, I will discuss the performance practice for the various stages of the phase in more detail.

In the sextet *Sydney Polypulse*, I sought to foreground phasing itself as a compositional texture. One starting point was the choice to create three duos in order to exploit the phasing technique, matching each duo loosely according to tessitura (flute with violin, bass clarinet with cello, piano with vibraphone). The tempi of the musicians in each duo would be linked by their phase length. In the full-ensemble polytempo passages, my intention was that both the duo phases and tutti texture would be audible, in order to create a multilayered sound. With this starting point, I could begin to form a method to explore approaches to the choice of tempi. Essentially there are two parameters for each duo that determine the individual tempi: the *base tempo* of the slower voice and the *duration of the phase*, as a result of the relationship between the base tempo and the tempo of the faster second voice. To create a calm atmosphere for the beginning, exploring very subtle speed differences, I chose a relatively slow tempo, experimenting in the range between 40 and 80 bpm for the *base tempi*. Andante (walking pace) might be too fast, largo (broadly) too slow. Adagio (at ease) captures the quality I was looking for, which is around 60 bpm.[42] The *duration of the phase* refers to the time it takes for the two voices of repeated notes to complete one phase cycle as shown above in example 4.34.[43] For example, a combination of one voice at 60 bpm and a second voice at 80 bpm - a 4:3 speed ratio - is a quite short cycle, lasting three seconds in this combination of tempi. For me, there is a metrical feeling to these cycles, each completion functioning musically as a single measure. This accords with music theorist Christopher Hasty's view that meter can arise in "measures that are longer than bars" and that larger groupings may be experienced with their own sense of metrical "rightness" (Hasty, 1997, p. 182).

Example 4.40. violin: 60 bpm, flute: 80 bpm, audio.

This phase duration was too short for the longer phrases I envisioned for this piece. On the other hand, a second voice at 61 bpm would yield a ratio of 61:60, meaning a single cycle would last an entire minute.

Example 4.41. violin: 60 bpm, flute: 61 bpm, audio.

While taking such a duration to follow all the miniscule timing gradations between two notes in such a long phase is certainly fascinating, the musical phrase created would lead to a work of much larger dimensions. The commission was for a work of 8 to 12 minutes and I wanted to have space to develop a variety of approaches to the polytempo application in multiple sections.

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[42] The correlation between the Italian terms and bpm is not standardized among literature and practice.
[43] The formula to determine the duration of a phase is: time (in seconds) = 1 / ((tempo B - tempo A) / 60)

To scope out some possibilities at the base tempo of 60 bpm, the following tempi from 80 bpm down to 61 bpm are listed, along with their corresponding tuplet, duration, and audio example.

- 80, 60 bpm - 4:3 - 3 second phase
- 75, 60 bpm - 5:4 - 4 second phase
- 72, 60 bpm - 6:5 - 5 second phase
- 70, 60 bpm - 7:6 - 6 second phase
- 68.6, 60 bpm - 8:7 - 7 second phase
- 67.5, 60 bpm - 9:8 - 8 second phase
- 66.6, 60 bpm - 10:9 - 9 second phase
- 66, 60 bpm - 11:10 - 10 second phase
- 64, 60 bpm - 16:15 - 15 second phase
- 63, 60 bpm - 21:20 - 20 second phase
- 62, 60 bpm - 31:30 - 30 second phase
- 61, 60 bpm - 61:60 - 60 second phase

Example 4.42. Different phase speeds, audio.

In *Sydney Polypulse*, I deemed a phase length of 20 seconds to be a suitable compromise for the work's duration: long enough for beautiful slow phasings, but not too long to require a work of greater length. For a 20-second phase at 60 bpm, the second voice needs to be 63 bpm, which simplifies to a 21:20 tuplet relationship.

Example 4.43. 63, 60 bpm - 21:20 - 20 second phase, audio.

Elements for the perception of speed in polytempo music

Another perspective I took while choosing the tempi was to examine the question of how the phasing would *sound*. More specifically, how discernible would the phasing details between two instruments be? Would the change of the timing relationship between two voices become labored and predictably plodding, or too fast and difficult for the listener to follow, leading to a different character than intended?

The choice of tempo plays an essential role. The slower the tempo, the more time available to hear subtle differences in speed, yet, if other musical parameters are kept relatively stable, the music can feel less energetic and risks becoming overly predictable. At faster tempi, the pulse can feel more exciting, yet the subtleties are glossed over. I tested combinations in both digital audio and notation software, assessing these trials through what I call "the filter of my own body": tapping, singing, listening, and physically sensing the results while reflecting on the musical goals. The aim was to find a middle ground between the two extremes.

During this process, I discovered that the duration of the phasing has a direct impact on the overall perception of speed, independent of the tempo:

- Short phase duration → music feels faster
  For example: Example 4.44. 80, 60 bpm - 4:3 - 3 second phase, audio.

- Long phase duration → music feels slower
  For example: Example 4.45. 61, 60 bpm - 61:60 - 60 second phase, audio.

I believe that this experience results from two intertwined factors: the evolving relationship between the two voices across iterations, and the subsequent metrical length. For the 4:3 combination (80 and 60 bpm), the substantial speed difference between the voices leads to a marked change in their rhythmic relationship with each repetition, instilling a feeling of rapidity. That high rate of change also culminates in a shorter cycle, and thus also a sensation of shorter measures. Shorter measures evoke a quicker pace compared to extended measures, like those produced by a 61:60 combination.

Another determinant of the identity of speed in a polytempo duo is the individual tempi (in bpm) of the voices. An 80 and 60 bpm duo encompasses both adagio and moderato simultaneously. When the tempi are closer together, such as 63 and 60 bpm, the dual temperament is reduced and the overall sound aligns more closely with adagio.

To sum up, the factors influencing the sensation of speed in this polytempo music include:

- the rate of change between iterations in the distance between two notes
- the phasing duration between the voices, leading to varied metrical lengths
- the tempi of the voices

The first two elements are interconnected, influencing each other, while the third operates autonomously. This implies that the base tempo can be selected to either accentuate or counteract the phasing speed. For instance, a piece with a 4:3 ratio, having a brief phase length, can be executed at a brisk tempo to amplify its brevity or at a languid pace, opposing its inherent speed.

- 4:3 at 120 bpm
- 4:3 at 50 bpm

Example 4.46. 4:3 at different speeds, audio.

In a 61:60 ratio, which has a very long phase length, the same options yield similar results: a fast-tempo pulsing with two slightly different speeds at the same time, or a slow tempo study into miniscule changes between the timing of two repetitive notes.

- 61:60 at 120 bpm
- 61:60 at 50 bpm

Example 4.47. 61:60 at different speeds, audio.

As the effect shown by the different Beethoven speeds, the choice of faster or slower overall tempi profoundly influences how the material is experienced, determining which musical details are foregrounded and which are backgrounded.

Three duos of Sydney Polypulse

When one or more further layers are added, the polytempo takes on several additional qualities. Primarily, multiple different phases occurring at the same time create a multilayered sound with many more audible details. However, as more layers are added the density of information can become overwhelming, leading the listener to shift focus from the individual details to the overall texture - seeing the “forest” rather than each individual “tree.” At this scale, I appreciate the beauty of a composite sound made from many interlocking parts, where regularity remains perceptible yet embedded within a complex, almost incomprehensible, mathematical structure. This balance between recognizability and intricacy is one of my primary goals in these polytempo works.

As outlined earlier, I chose phases of approximately 20 seconds for *Sydney Polypulse*. The next step was to determine how to implement this within three duos, each with a different base tempo. I explored three scenarios in which the duos' base tempi were:

- a) far apart,
- b) moderately close, and
- c) very close together.

All examples revolve around a general tempo centre of 60 bpm.

- a) Example 1, widely spaced: Example 4.48. [40, 42, 60, 63, 80, 83 bpm], audio.

  Duo 1: **40** - 43 bpm (13:12)
  Duo 2: **60** - 63 bpm (21:20)
  Duo 3: **80** - 83 bpm (27:26)

- b) Example 2, moderately spaced: Example 4.49. [50, 53, 60, 63, 70, 73 bpm], audio.

  Duo 1: **50** - 53 bpm (17:16)
  Duo 2: **60** - 63 bpm (21:20)
  Duo 3: **70** - 73 bpm (23:22)

- c) Example 3, closely spaced: Example 4.50. [60, 61, 62, 63, 64, 65 bpm], audio.

  Duo 1: **60** - 63 bpm (21:20)
  Duo 2: **61** - 64 bpm (21:20)
  Duo 3: **62** - 65 bpm (21:20)[44]

With six distinct tempi, there are 15 simultaneous phasings: each voice interacting with the other five (5+4+3+2+1). In example 3 the close speeds between all the players create a number of longer phases of around 60 seconds. However, as mentioned above, in order to make space in the sound for the 21:20 phases within each duo I put each one into an octave separate from the other duos.

Finally, I chose to have all the voices as close together as possible, as reflected in example 3. At first it may sound as though all the players are playing at the same speed, yet as time passes, the relationships of the articulated notes between players change subtly. The sound is quite different from the mix of many disparate speeds at the same time when the tempo areas of the duos were spread apart (examples 1 and 2).

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[44] While the percentage of difference of 3 bpm varies in different speed areas, e.g. 63 is 5% faster than 60 bpm and 163 is only 1.8% faster than 160 bpm, in the relatively similar speed-options I was exploring, the differences were negligible.

After establishing a close series of tempi, I explored one further option: stacking all the tempi 3 bpm apart, which leads to phases of around 20 seconds between all adjacent speeds.

Example 4.51. 60, 63, 66, 69, 72, 75 bpm, audio.

This setup yielded an overall sound that felt too brisk for the slower character I sought. Consequently, I devised a second version, slowing the base tempo by 10 bpm:

Example 4.52. 50, 53, 56, 59, 62, 65 bpm, audio.

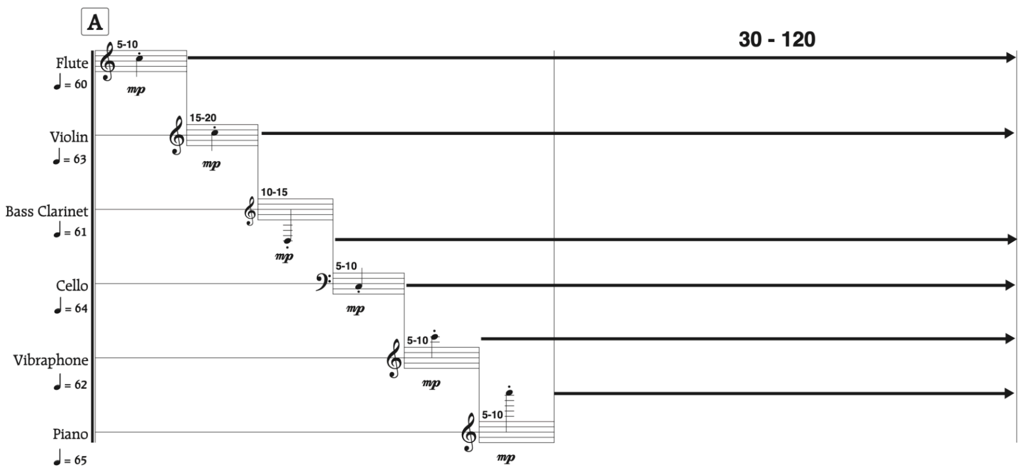
While this captured a slower overall tempo, there was still a wide disparity in speeds between 50 and 65 bpm in the outer voices, creating a somewhat chaotic texture. Maintaining 65 bpm as the fastest tempo, I came back to the smaller stacking of tempi: 60, 61, 62, 63, 64 and 65 bpm.

Example 4.53. 60, 61, 62, 63, 64, 65 bpm, audio.

This configuration captured, finally, the slow moving system of polytempo I was looking for. To emphasize the 20-second phases, I opted for a 3 bpm difference for each duo from the start. This led to the chosen tempi for the piece:

- Duo 1: 60 (flute) - 63 bpm (violin)
- Duo 2: 61 (bass clarinet) - 64 bpm (cello)
- Duo 3: 62 (vibraphone) - 65 bpm (piano)

Sydney Polypulse begins with all the instruments simply repeating the pitch 'C' at their own tempo. The entrances are sequential, each one after 5 to 10 seconds. Once all the musicians have entered the phasing texture simply runs its course for 30 seconds up to 2 minutes.



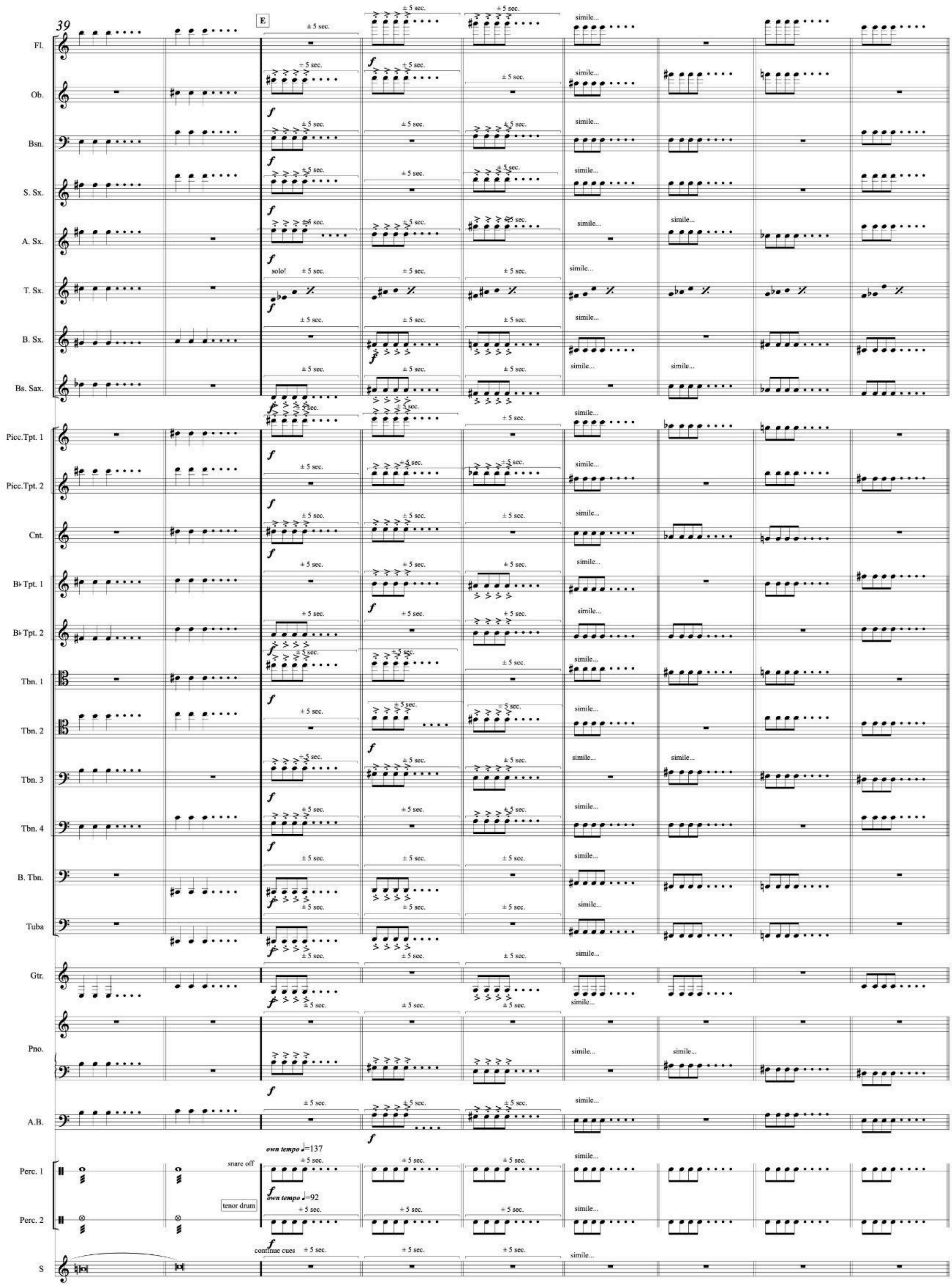
Example 4.54. *Sydney Polypulse*, video.

4.5.5 Implementations of note values

As mentioned above, using merely quarter notes at different speeds results in a limited palette of speed to work with. In this section I outline the development of my approach to creating different speeds through the use of tuplets and rhythms. Quarter notes, a tuplet of 1 note per beat, can be exchanged for other tuplets, such as triplets or 16th notes, and rhythms can be implemented to give the individual lines more character.

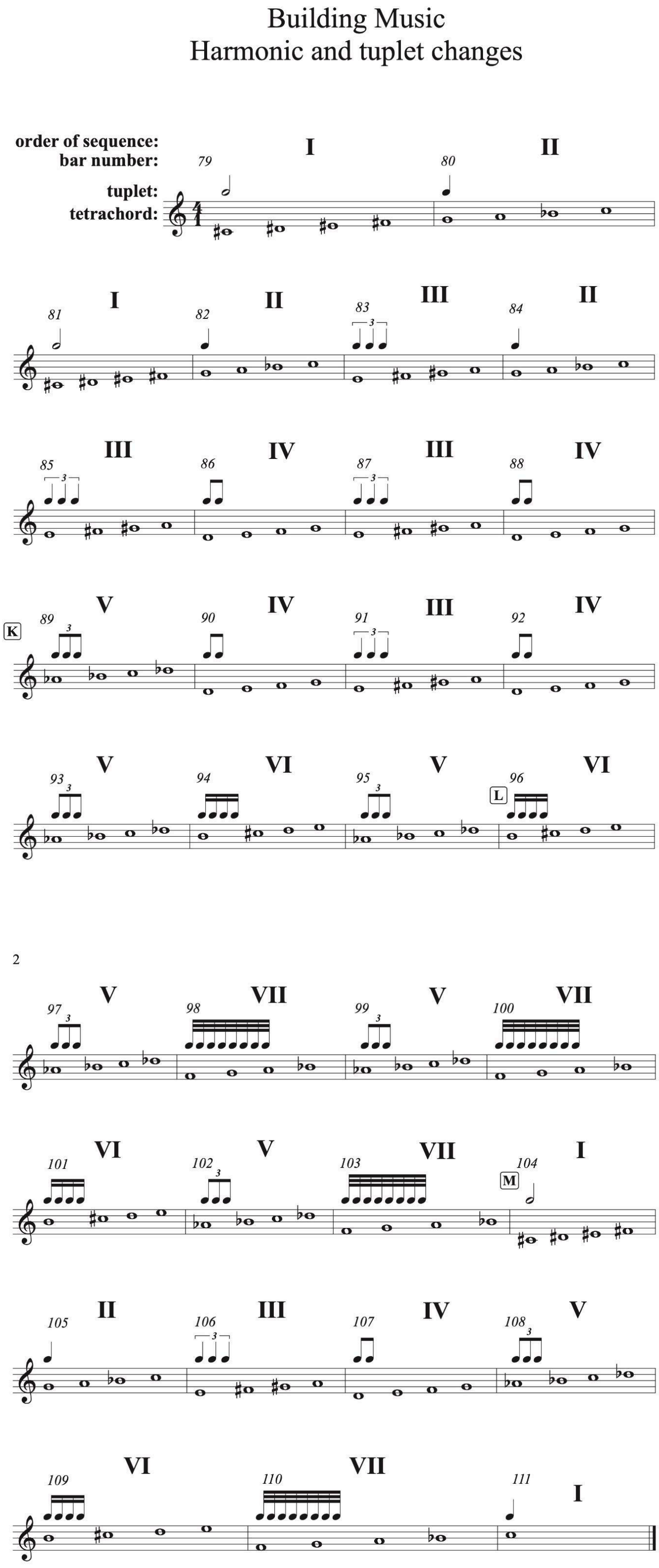
The repeated notes in *Building Music* begin as quarter notes but other note values are used later in the work, from whole notes up to 32nds. While the 16th note speed is taken as the upper limit for the range of tempi, as mentioned above, that is the case only for the piccolo trumpet 1, who plays at 160 bpm. 16ths at this tempo equate to individual notes at 640 bpm (160 bpm x 4 (16ths per beat)). When 32nds are employed in the work, they always surpass this maximum speed. Given that the slowest player's tempo is 86 bpm, this equates 32nds to 688 bpm (86 bpm x 8 (32nds per beat)). The practical result is that when 32nds are notated, they are simply to be played as fast as possible. This also generates a polytempo texture, since each musician will have a different personal limit to their speed of articulation.

In *Building Music* I kept the tuplets in all parts the same, only changing to another tuplet simultaneously in all the voices, which creates textures that shift in blocks; there is no mixing of different tuplets between the players. For example, at the first shift (at letter E, see below), the polytempo texture transitions from quarter notes to 8th notes for all players, effectively doubling the density.



Example 4.55. Building Music switch to double speed, score excerpt. Video excerpt.

In the final section, where there is both a harmonic shift and speed change for each bar, their correlation was mapped out in a straightforward one-to-one ratio. Each of the six harmonies - tetrachord clusters distributed among all the players - is sequentially linked to one of six tuplets, increasing in speed. The passage unfolds as a sequence of those combinations.

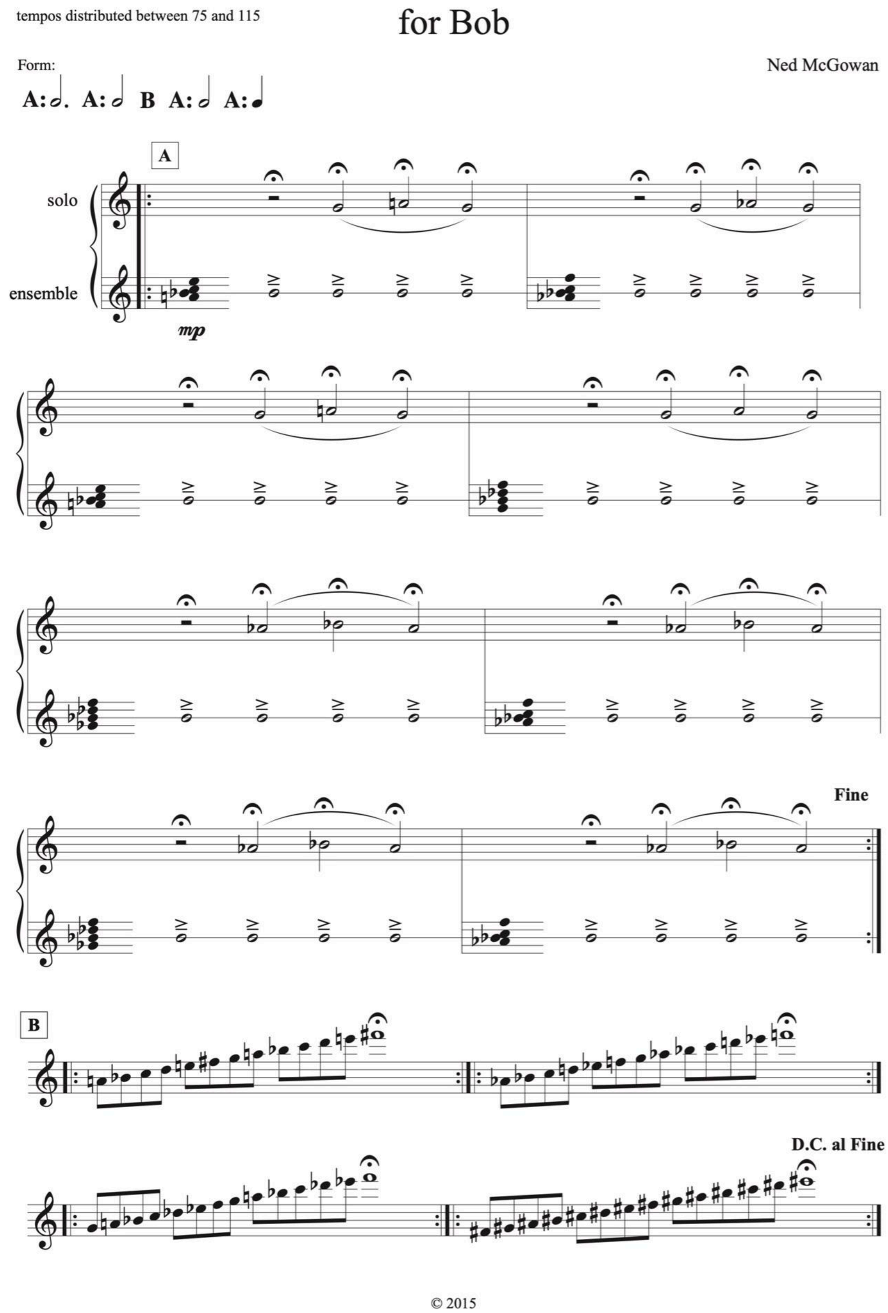


Example 4.56. *Building Music,* Part 4, harmony and speed switches, score. Video excerpt.

The calm texture I was aiming for in *For Bob* called for relatively longer durations. This can be achieved in two ways: with very slow tempi or through the use of notes longer than quarters. I chose longer note values for several reasons, the first being that the opening section combines multiple tempi with dotted half notes. The chosen tempi range is 75 to 115, which equates to notes of 25 to 38 bpm (⅓ of 75 to 115). While metronomes can produce these tempi, the long durations are difficult to synchronize because of the extended temporal gaps between cues. Dotted half notes at 75 bpm offer three times the synchronization information compared to quarter notes at 25 bpm. A further reason was that this approach enabled a progressive acceleration of the texture in subsequent iterations of the A section (see example 4.58 below), moving from dotted half notes to half notes and finally to quarters.

In the contrasting B section, the players switch to runs of faster eighth notes at their individual tempi.

Here is the one-page score of *For Bob:*



[45]

Example 4.57. *For Bob*, score.

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[45] From the score instructions: "At the beginning of each bar all the instruments, except the solo lines, will choose a note from the chord and keep it throughout the whole bar. Chordal instruments could choose more notes or the entire chord. In sync with your metronome, you repeat your note until the next cue. The length of your repeated note for all the bars in A, either a dotted half note, a half note or a quarter note, is determined by which part of the form you are in (AABAA)."

Sydney Polypulse begins similarly to *Building Music*, with quarter notes for each musician at their own tempo. Although this worked well for the opening unison section, I sought techniques to create a larger palette of speeds, driven by the research detailed above and my goal to achieve a form with varying levels of tension.

The specific problem was how to move beyond the single-speed limitation of quarter notes in order to create a broader range of perceived motion within the ensemble texture. My solution was to introduce tuplets as a tool to extend the speed range. For example, applying a 3:2 ratio to a tempo of 60 bpm produces an effective tempo of 90 bpm. The set of tuplets I used, arranged in order of increasing speed, was:

- 4:3 (dotted eighth notes)
- 3:2 (triplet quarters)
- 2:1 (eighth notes)
- 3:1 (triplet eighth notes)
- 4:1 (sixteenth notes)
- 6:1 (sixteenth-note sextuplets)
- 8:1 (thirty-second notes)

As previously discussed regarding *Building Music*, all the voices (in their different tempi) took on the same tuplet at the same time, creating a uniform speeding up and slowing down. One focus of *Sydney Polypulse* is on the specific relationships between individual voices, and I aimed to mix tuplets between voices, achieving greater speed separation than the initial 1 bpm difference.

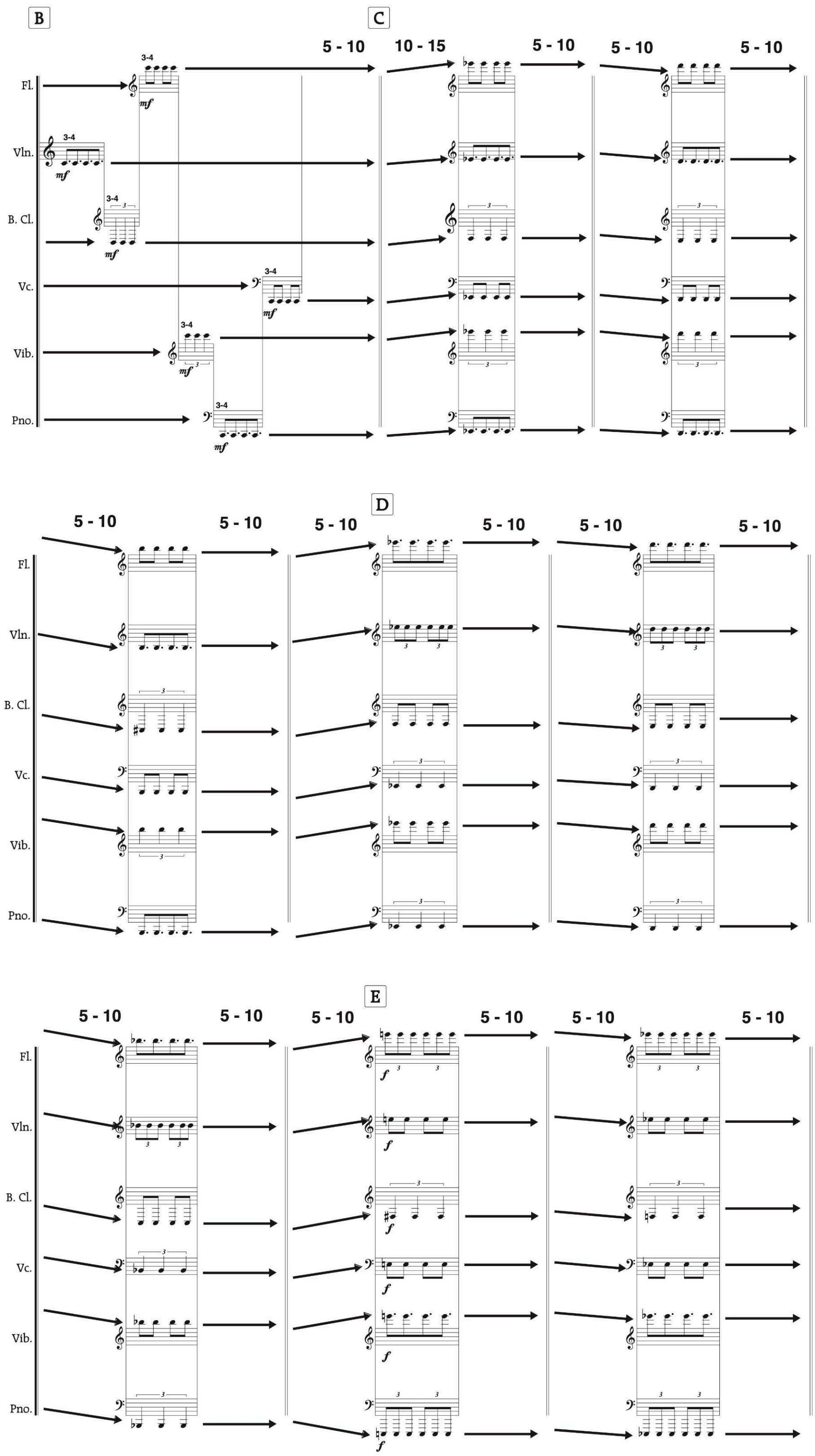
Letter B (score below) introduces several tuplets on different octaves of the opening pitch of C, and then, beginning at rehearsal letter C, harmonic developments begin to occur. As the ensemble progresses through the pitch unisons of Eb, D, B, Eb, D, Bb, E, Eb and A, the mix of speeds among the instruments periodically changes, creating a different texture each time.

To streamline the compositional process, I translated each tuplet ratio into its decimal equivalent:

- 3:1, triplet 8th notes = **.33**
- 2:1, 8th notes = **.5**
- 3:2, triplet quarter notes = **.67**
- 4:3, dotted 8th notes = **.75**

This conversion provided a clear framework for planning speed changes across instruments at different rehearsal letters. The chart below shows the tuplet-decimal assignments for each instrument, along with the resulting bpm in parentheses.

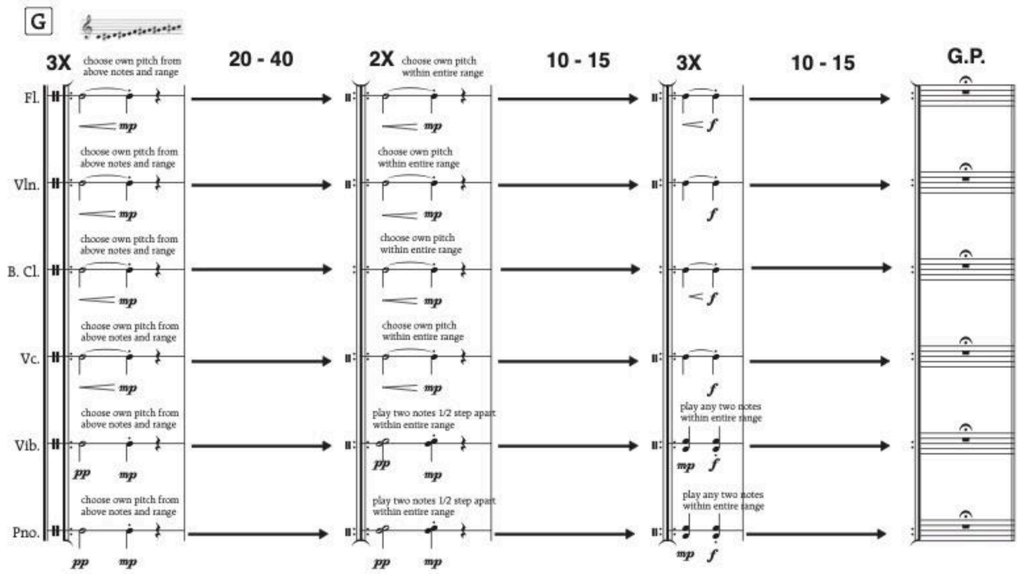
Rehearsal letter	A	B	C	D	E
- flute	**1** (60 bpm)	**.5** (120 bpm)	**.5** (120 bpm)	**.75** (80 bpm)	**.33** (180 bpm)
- violin	**1** (63 bpm)	**.75** (84 bpm)	**.75** (84 bpm)	**.33** (189 bpm)	**.5** (126 bpm)
- bass cl.	**1** (61 bpm)	**.67** (92 bpm)	**.67** (92 bpm)	**.5** (122 bpm)	**.67** (92 bpm)
- vlc.	**1** (64 bpm)	**.5** (128 bpm)	**.5** (128 bpm)	**.67** (96 bpm)	**.5** (128 bpm)
- vibraphone	**1** (62 bpm)	**.67** (93 bpm)	**.67** (93 bpm)	**.5** (124 bpm)	**.75** (83 bpm)
- piano	**1** (65 bpm)	**.75** (87 bpm)	**.75** (87 bpm)	**.67** (98 bpm)	**.33** (195 bpm)



Example 4.58. [*Sydney Polypulse*, B to E](), score excerpt, video excerpt.

From letter C through letter E, the players have unison pitches (in different octaves) but the switches between tutti unisons are staggered as players choose to switch at their own time (the angled arrows). The result is a slow dissonant appoggiatura effect between each new pitch (the straight arrows), creating moments of tension and resolution.

Later in the piece, longer notes, such as half notes and rests, are also used to create basic rhythms.



Example 4.59. *Sydney Polypulse*, G, score excerpt. [Video](#).

4.5.6 The use of metronomes

During performances of both *Building Music* and *For Bob*, one important aspect of my own experience was a compulsive focus on achieving a perfect equal polytempo, inspired by the computer models I had assembled in the testing phase. Even with the ensemble's massive sound, when players maintain uniform repeated notes, one can discern the repetitiveness of individual voices. In this texture, the phasing relationships between layers can be too overwhelming to fully track as a listener. For the polytempo texture to produce the polyphonic effect I intend, each player must follow their metronome with unwavering precision, maintaining their own distinct speed. From observation, even slight inaccuracies cause audible irregularities in the repetitions, disrupting the intended polytempo sound.

In *Building Music*, I instructed musicians to follow the blinking light of silent metronomes placed on their music stands. The metronomes would be in silent mode and the players could see the blinking in their peripheral vision while looking at their parts. This provided players with a visual pulse, keeping the sonic space uncluttered for the music.

Example 4.60. [blinking metronome](#), video.

Although generally successful, this setup occasionally produced timing errors between players. These errors become audible during synchronizations, particularly when two voices rhythmically align for several iterations. This effect shouldn't occur, of course, since the natural result of any two voices in different tempi is a constant phasing. The large ensemble in *Building Music* somewhat masked this issue with its massive sound. However, in thinned-out sections, this unintended synchronization was evident.

This problem persisted even with the spatializing of closely matched tempi, as previously mentioned. One solution would be to spread the players of the ensemble even further apart. Another approach could involve eliminating the ensemble, recording each voice separately, and playing them back together, through a multiarray speaker setup. However, both options undermine one of my central artistic aims: maintaining ensemble cohesion through the musicians' ability to hear and respond to one another - a core value in chamber music and equally important in my polytempo works. As such, I did not pursue these approaches further.

At this point I was unsure how to correct the problem beyond simply "more practice." When I embarked on my next polytempo piece, *For Bob*, I gained insights that shed light on aspects of both the problem and its solution.

Here is an example in the flutes version of *For Bob* where the (undesired) synchronization between the players is clearly audible.

Example 4.61. *For Bob*, for flutes, problem spot 1, video excerpt.

The fourth arrangement of *For Bob* was for the 31-tone Fokker Organ and solo flute/contrabass flute. The unique technical possibility of this organ is that it is controllable via MIDI, making it a suitable acoustic instrument for the strict polytempo technique, being driven by a computer. As a reference, here is a clip from the MIDI version with the Fokker Organ.

Example 4.62. *For Bob*, for Fokker Organ, spot problem spot, video excerpt.

Since it was controlled by a computer, the accuracy of polytempo speeds by the MIDI Fokker Organ was ideal, and all of the multiple simultaneous layers and their interactions were audible. It missed, however, the color of human interpretation: individual dynamics, articulations, tone colors, and interaction between the players, to name a few qualities.

In the Jerboah version, the musicians opted to play the piece using earbuds to *hear* their metronomes, instead of watching the blinking lights. The resulting rhythmic polytempo sound was stunningly accurate.

Example 4.63. *For Bob*, for Jerboah, audio.

This version opened the question of whether pulses given by sonic cues can be more accurate than visual cues, which led to investigate the different possible modalities for metronomes: auditory, visual, tactile, and combinations thereof.

Sensory modalities for metronome cues

Auditory cues are sounds, musical or non-musical, that we hear and synchronize with, such as the playing of nearby musicians or the click of a metronome. Synchronizing with a recording of a drummer, or with a cellist who maintains steady timing, is typically straightforward.

Visual cues may come from a conductor, the violinist's bow, a blinking metronome or some other visual chronometer. Research has shown that spatial-visual information is more reliable than flashes (Grahn, 2012, p. 51-61). Examples include the approach of a timpani mallet to the drumhead or the animated pendulum on some digital metronomes.

Tactile cues are sensations we feel within or on our bodies, manifesting as either kinesthetic or haptic forms. Kinesthesia is the awareness of the location and movement of a foot, finger or head, for example. We track them either in repetitive and non-repetitive motions. Repetitive movements, like moving a foot up and down, facilitate better time-keeping as they can be easily standardized. Haptic sensations are felt vibrations located on one's skin.

According to psychologists Katherine Ammirante, Aniruddh Patel, and Frank Russo, our ability to synchronize with a metronome pulse is much more accurate with auditory clicks than visual flashes, suggesting an enhanced auditory-motor coupling for rhythmic processing (Ammirante, Patel & Russo, 2016, pp. 1882-1890). This study aligns with my experiences in *Building Music*, where I noted rhythmic challenges with flashing metronomes, and observed improved accuracy with earpiece metronomes in the Jerboah rendition of *For Bob*. Further, when comparing the results from auditory stimuli to tactile stimuli (delivered to the fingertip), Ammirante, Patel and Russo found no significant difference in response time, suggesting that a tactile metronome can also be more effective than flashing metronomes. This finding is pertinent to polytempo music performance methods, especially since a new tactile metronome, the Soundbrenner, was introduced in 2014 (Ammirante, Patel & Russo, 2016, pp. 1882-1890).

The Soundbrenner, a watch-like device worn on the body, produces a vibration that can be felt. It has several different placement possibilities: on the wrist, on the leg, or with a body strap. After testing these options, I favor the body strap because it creates a pulse close to where I feel my inner pulse - at the center of my torso. The other musicians wore their Soundbrenners on their wrists or ankles and at least one musician claimed that the wrist placement was too distant to effectively follow. This aligns with Ammirante, Patel, and Russo's findings that performance can vary significantly based on the location of a tactile cue, be it on a fingertip or toe (Ammirante, Patel & Russo, 2016, pp. 1882-1890). While other musicians adapted well to the wrist placement, drawing a direct correlation between practice and the study proved elusive.

Even while feeling the tactile sensations of the Soundbrenner, I experimented with including the visual flash given by my smartphone. However, psychologists Rachel L. Wright, Laura C. Spurgeon, and Mark T. Elliott showed that combining both auditory and visual cues produces slightly better results than auditory cues alone (Wright, Spurgeon & Elliott, 2014). While this multisensory attention to both tactile and visual modalities of the metronome improved rhythm, I felt musically constrained to a singular focus on the metronome. By omitting the flashing and focusing solely on the metronome's vibration, I could devote more attention to surrounding sounds and musicians. This makes sense since I can look elsewhere while still feeling the pulses. Given that interaction is fundamental to chamber music and my polytempo compositions, the benefits of a visual connection with fellow musicians surpass the slight edge of multisensory cues. Furthermore, vision is needed to follow the score. If hearing concentrates on the music and instrument, and sight on the score and fellow musicians, it naturally positions touch as the best strategy for following the metronome's pulse. For live music, the haptic metronome is preferable because of its superior accuracy over a flashing metronome, and its silence. In other words, there is no audible click interfering with the sounding music. For *Sydney Polypulse,* I decided to use the Soundbrenners as an integral part of the performance.

Undoubtedly, factors like practice, adjustment, individual abilities such as improved focus or foot-tapping influenced the final choices. The availability of Soundbrenner straps, with only one body strap, was also a consideration. While there weren't studies addressing all the variables, as is typical for musicians, we found a way. We began by testing methods, evaluating whether challenges could be addressed with practice or if a different approach was necessary. Although one study indicates haptic metronomes lose effectiveness the farther they are from the brain (Ammirante, Patel & Russo, 2016, pp. 1882-1890), our percussionist preferred it on her ankle, allowing her wrists freedom to play the vibraphone. At times, choices that may seem physiologically less optimal are made for practical reasons, with any ensuing challenges tackled through practice, concentration, and expertise. This illustrates how practice-based inquiry can offer insights and pragmatic solutions that complement and add value to findings in other scientific fields.

4.5.7 Coordinating musicians in polytempo music

Coordination strategies in other polytempo works

When each musician follows a different tempo, metric coordination across the ensemble, for example aligning “four beats per bar,” quickly becomes untenable. Four beats at one tempo necessarily occupy a different duration than four beats at another tempo. The first compositional decision in polytempo music therefore concerns the basis of coordination. The layers may meet at predetermined points; one layer may function as a reference, or coordination may remain largely local and contingent.

One established solution is to distribute authority across tempo groups through multiple conductors. Works such as Stockhausen’s *Gruppen* and Earle Brown’s *Available Forms II* employ more than one conductor so that different subsections can maintain independent tempo trajectories. The approach is effective for a small number of tempo strata, but it does not scale to situations in which each individual player inhabits a distinct tempo. In that case, a conductor per musician would be required, which is impractical in an ensemble of twenty-four.

A second solution relocates coordination from interpersonal entrainment to a mechanically fixed temporal mapping. In *New Musical Resources*, Henry Cowell proposed ratio tempi and noted that the player piano roll allows rhythmic complexities to be cut directly into a time bearing medium. This remark catalyzed Conlon Nancarrow’s exploration of polytempo relationships in the *Studies for Player Piano*, where temporal positions are encoded spatially as punched holes in the paper roll. Because note speeds translate straightforwardly into distances on the roll, the instrument can realize tempo ratios with a precision that would be difficult to sustain in a human ensemble. György Ligeti’s *Poème Symphonique* offers a related example in which a technology designed to produce a uniform pulse becomes the generator of a complex temporal field when multiplied. A metronome is built to enforce steadiness, yet a group of metronomes produces a shifting polytempo texture through the inevitable divergence of their mechanisms and decay times.

A third family of solutions emerges with computers, which enable individualized tempo streams to be delivered to performers via electronic click tracks. In Kyriakides’s *Wavespace* and Sinan’s *At First*, a computer distributes separate click tracks so that each musician can follow a dedicated tempo line while remaining aligned with a global timeline shared by the system. This approach makes coordination explicit without requiring performers to negotiate tempo relationships in real time. It also shifts the rehearsal problem from aligning beats on the page to developing a reliable bodily and attentional relationship with the click, especially when tempo changes or phase relationships are complex.

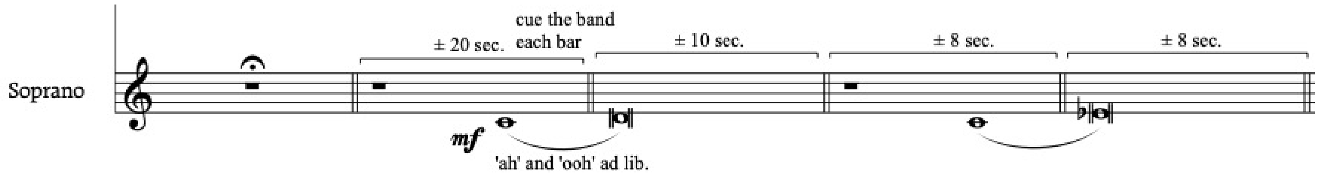
A fourth possible approach is to treat coordination as an emergent outcome of a performer’s agency and rehearsal practice, rather than as an externally imposed synchronization mechanism. In my work “Telescopic Ladder,” from the work *Tools* I tap into the potential of musicians realizing polytempo relationships via improvisation. The musicians are asked to choose and perform their own tempo that differs from the other musicians. While practice is essential, this directive proved simpler for musicians than realizing comparable temporal complexity through extensive tuplet notation within a single shared metric framework.

Example 4.64. [*Tools*, "Telescopic Ladder", random speed section], video excerpt.

Coordination strategies in my three works

In the three polytempo works I have focussed on in this chapter, the possibility to have the metronome cue the musicians was an essential starting point. The synergy between concept and technique in creating feasible polytempo music occurred at the initial conceptual stages of the compositional process.
As mentioned, in *Building Music* each musician has a metronome giving them their tempo, but structuring the global changes from bar to bar and from section to section requires a cueing technique for the entire ensemble. The option exists to have all the players led by a click track computer system coordinating all the different speeds, as is done in *Wavespace*. But because the piece's dense, overlapping speeds quickly create a stable "chaos texture," exact simultaneity across all players isn't necessary. The texture sounds consistent whether or not the bars align perfectly, so the metronomes alone suffice.

My solution to cueing the bars was to time their lengths in approximate number of seconds and to have the soprano cue each bar with her arm. In this case the singer can time the harmonic flow with her melodic lines, which are also in part determined by how long she can hold a note before needing to take a breath.



Example 4.65. *Building Music*, score excerpt.

This process can be seen here:

Example 4.66. *Building Music*, video excerpt.

In *For Bob*, again a single musician (or conductor) cues the bars where the harmonies switch. While the piece has a recurring vocal melody, in this piece the melody begins and ends in the middle of each bar. This allows bar lengths not limited by a singer's breathing. The polytempo motor simply keeps running until the cue is given for the switch. There are no elements to indicate any length of phrase and the music gives no further clues as to how long each bar will last. This allows for longer bars, which can contribute to the sense of timelessness intended with this piece.

Example 4.67. *For Bob*, bars 1 to 3, video excerpt.

For the MIDI-controlled Fokker Organ version, however, I had to pre-program bar lengths. This meant committing to durations before the performance, which sometimes caused the melody to be cut off.

Example 4.68. *For Bob*, for Fokker Organ problem spots, video excerpt.

The fix was to build a Max MSP patch that kept the organ's polytempo running indefinitely, letting me, as the flutist in the performance, trigger harmonic changes with a MIDI pedal in real time. This restored the flexibility I wanted, making the cues responsive to the moment rather than predetermined.[46]

Example 4.69. *For Bob*, for Fokker Organ, with Max patch control, audio excerpt. Video excerpt.

[46] These factors are discussed in Chapter 2.

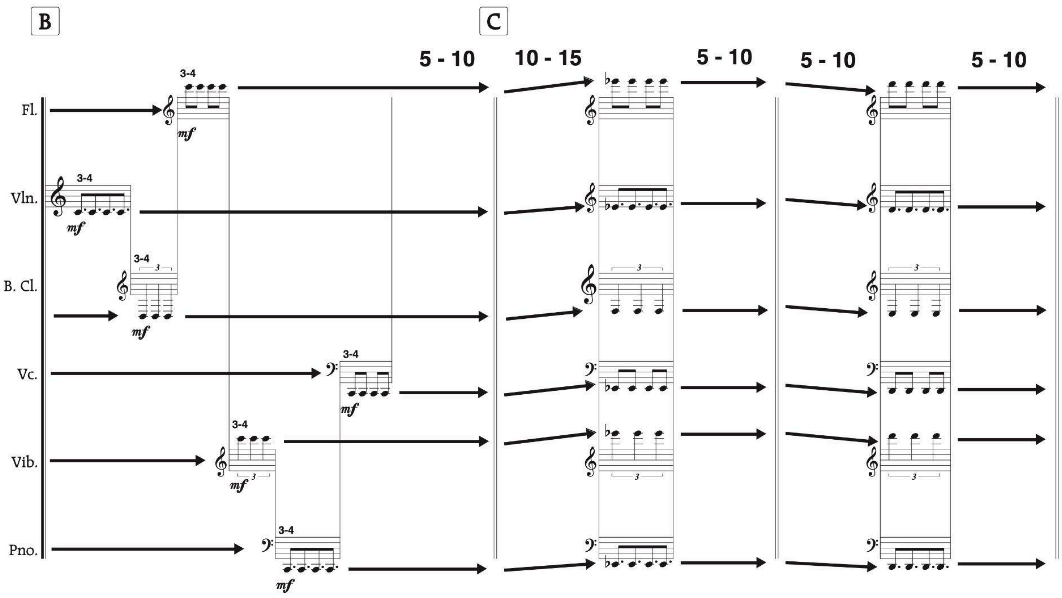
In *Sydney Polypulse* a number of different strategies for cueing are utilized. In section A (Example 4.55), musicians enter on their own, guided by time intervals given in seconds, similar to *Building Music*. Letter C focuses on a morphing effect I had first noticed in *Building Music*: when everyone changes pitch at a cue, their individual tempi mean the change doesn't happen all at once. Each player switches on their next beat, creating a gradual blend of old and new pitches. In *Building Music*, with faster tempi, this morph can be perceived as unfolding within the span of a single beat.

Example 4.70. *Building Music*, morph transitions, video excerpt.

In *For Bob* the effect is more pronounced due to the slower tempi and longer notes.

Example 4.71. *For Bob*, morph transitions, video excerpt.

In *Sydney Polypulse*, I made this gradual change a core feature. Here, musicians take 10–15 seconds to move from C to Eb, creating an audible appoggiatura effect - a momentary tension as both pitches coexist, resolving only when all have changed. Since the timing is up to each player, they can shape that tension individually.



Example 4.72. *Sydney Polypulse*, score excerpt. Video excerpt.

From section F to J, bar changes are cued by a single ensemble member, keeping the group connected even while the underlying polytempo runs independently.

Example 4.73. *Sydney Polypulse*, transition from E to F, video excerpt.

Again, as in Ligeti's *Poème Symphonique* and my own "Telescopic Ladder," strategies devised to handle the practical constraints of coordination with the available instruments and technologies become integral to the identity of the piece rather than remaining background solutions.

4.5.8 performance practice of Sydney Polypulse

In February 2022, I rehearsed and performed *Sydney Polypulse* with five master's students from the Fontys Academy of Music and Performing Arts in Tilburg. Joining the ensemble on the flute part, I was able to experience first-hand the performative aspects of the piece and to gain an understanding of it from the player's point of view. Here I outline a number of topics that came up during the rehearsals and performance.

Polytempo with different instruments: finding your "inner robot"

During the rehearsals we observed the different ways each of us plays our instrument and how that affects the articulation of the polytempo, how exactly the sound is created. For example, the motions of the piano, percussion and string instruments are binary in nature: up and down or left and right. These movements can be mechanized in a repetitive robotic manner, much like the binary movement of many time keeping devices: pendulums, pulsing quartz, oscillating atoms, etc. This can reduce variability in the timing of their notes.

As percussionist Russell Hartenberger, with over 50 years of experience performing Steve Reich's *Drumming*, describes it:

> I am reminded of the yogic principle of the elimination of outside distractions in focusing on simple physical actions, and for a percussionist, the attention to a single stroke is sound creation at its most fundamental level. […] The concentration, energy, endurance, repetition, rhythmic awareness, and physical motions in phasing are at the core of the performance practice of all Reich's music. (Hartenberger, 2016, p. 107)

The string instruments are somewhat more complex due to the variety of ways sound is produced. For example, sound can be created either by placing the bow on the string and creating a sudden fast movement, or by a circular action in the bow-arm. In the latter, the string is activated by the bow in motion, and the speed and contact time dictate the specific articulation and volume. The simpler hitting movement of the piano and percussion makes it easier for those players to synchronize with their metronomes. The flute and bass clarinet require setting the embouchure and starting the air, which involves an extensive set of muscles in the mouth and torso. While this is seemingly less directly binary in nature, earlier studies have also demonstrated that wind players have less variability than string players (Rasch, 1979).

In short, in polytempo, whatever the instrument, the goal is the same for performers: precise, repetitive motion with as little drift as possible. This is what I call finding your "inner robot."

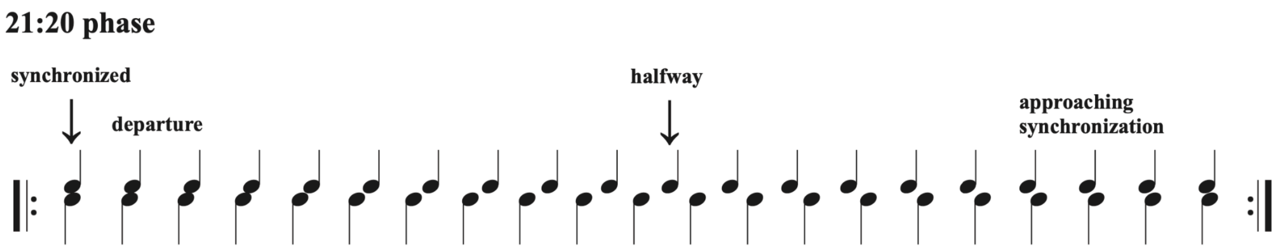
Subdivision

We also experimented with subdividing the pulse to improve steadiness. In theory, subdividing the pulse, whether physically or cognitively, provides more information to determine the steadiness of the pulse. The primary options for division are 8ths, 16ths, or 32nds. Dividing into many small units with 32nds, however, creates more events to keep track of, and at a certain density the demands on cognitive load outweigh any gained accuracy. At first, 16th notes seemed to be the best resolution. However, several musicians found tapping 8th notes more effective, alternating their feet in a left-right sequence. One student remarked that this might be because we are used to the movement of walking and maintaining a pace. Marcel Andriessen, percussionist and teacher at Fontys, believed that this was effective because of its physicality. He contends that we can sense time through our movement, a view supported by controlled experiments showing that moving along to a perceived beat improves timekeeping precisely when the external signal is absent, and that when movement during the silent timekeeping interval is withheld the advantage disappears (Manning & Schutz, 2011, p. 125). These results help to explain why tapping 8th notes in a left and right sequence, akin to walking, stabilized the pulse for several musicians in our trials.

Andriessen posited that subdividing the beat into 8th notes is effective due to the resultant afterbeat, which can be audibly and/or physically perceived. 16ths or 32nds might become too difficult to maintain, as mentioned above. Conversely, 8th notes create an upbeat in the note's articulation, a technique regularly demonstrated by percussionists and violinists using their sticks or bows. For wind instruments, which don't have a binary movement, the backbeat is generated bodily, through mechanisms like foot tapping or breath. In my own practice I use both. Control of small breaths to delineate time is natural for me as a flutist, and when that is not possible, for example while playing notes, then I switch to tapping my toe.

Concentration and the stages of a phase

As explained in the section about selecting tempi, the phasing duration between two voices stems from their tempo relationship. In *Sydney Polypulse*, I opted for a 21:20 phase for the duos, indicated strictly by metronomes set to 63 and 60 bpm. Working on playing this phase led to realizations about its structure. There are clearly audible markers in the phase, starting with the moments of synchrony and the halfway point. Hartenberger identifies these markers along with the ¼ and ¾ points in the long phases of that piece (Hartenberger, 2016, p. 97). In my experience with *Sydney Polypulse*, the areas demanding the most focus were those of departure from and return to synchrony between the two voices. These were challenging due to the proximity of the voices in timing.



Example 4.74. 21:20 phase.

Several factors may account for the difference between my experience and Hartenberger's in *Drumming*: in *Sydney Polypulse* we used metronomes; I chose a single repeated note rather than a patterned figure; and of course his depth of experience is exceptional. Artistically, *Sydney Polypulse* aims for a lucid, gradual phasing of single notes by six players, organized as three duos. This stands in contrast to the in-and-out-of-focus shimmer that arises in Reich's phased patterns in *Drumming*.

Example 4.75. *Sydney Polypulse*, introduction, video excerpt.
Example 4.76. Reich, phase from *Drumming*, video excerpt.

In the Fontys rehearsals we noticed a strong tendency to "stick" at the unison point. Pairs would remain synchronized for several beats, in some cases up to five beats, which already accounts for roughly a quarter of the 20-second phase, before they reasserted their metronomes and the phase continued. Although the following examples come from early rehearsals, the sticking effect is clearly audible.

- *Sydney Polypulse rehearsal clip 1*
- *Sydney Polypulse rehearsal clip 2*
- *Sydney Polypulse rehearsal clip 3*
- *Sydney Polypulse rehearsal clip 4*

Example 4.77. *Sydney Polypulse*, synchronizations, video examples.

At first, polytempo is unintuitive, and players must prioritize their focus on playing in time with the metronome, resisting influence from the timing of others. During the learning process, I proposed concentration strategies such as aiming to hit one's first note perfectly in sync with the metronome, then restarting with the same goal for the subsequent note. This type of focus creates an "in the moment" awareness which resets for each note.

I found this particularly difficult at these moments, especially when approaching synchrony. With practice, however, my attentional stance began to shift: near synchrony I focused more intensely on the metronome, while in the middle of the phase I allowed myself to relax that focus and instead listen to and enjoy the interaction of the two pulses. Developing the "inner robot," meaning the ability to lock attention onto an external timing reference when required while staying aware of the other musicians, is essential to bring polytempo performance to life.

Even when following a metronome, however, we are not machines. Microtiming deviations remain and typically fall in the range of about 50 to 100 ms relative to the metronome's ideal timing (Repp, 1999; Madison & Merker, 2002). In *Sydney Polypulse*, the stepwise difference between successive dyads in the phase is also on the order of tens of milliseconds, around 50 ms for many combinations.[47] This numerical overlap matters. It places the natural human fluctuation and the musical phase increment in the same temporal neighborhood, a region where fine control becomes difficult for conscious correction. Deviations in this band are not always expressive choices. They can also arise from physical and instrumental constraints, as discussed in section 4.5.8. Because the phase step and the microtiming variance occupy similar ranges, the pull toward synchronization exerts disproportionate influence on the progress of the phase. At times it becomes hard to distinguish whether one is hearing an intended phase step or an unintended microtiming drift.

Further, while playing I sometimes try to clarify salient phase moments by nudging timing forward or backward by very small amounts, with the intention of putting a temporal magnifying glass on those instants so they feel extended and legible. This works only if the partner does not make a similar adjustment at the same time. If both players "help," the nudges can cancel or compound in confusing ways, because both actions live in the same 50–100 ms corridor as the phase step itself. This is another concrete instance of the interaction between multiple rhythmic grids outlined in section 4.2: the fundamental grid, the expressive grid, and the partner's grids. In practice, only when the metronomes are separated by about 500 ms, which occurs toward the middle of the 20-second phase, do players feel genuinely unstuck and free from the syncretic pull.

This raises questions of performance strategy: should a player use microtimings to highlight certain parts of the phase, perhaps lingering at a particularly beautiful moment? Or should the focus remain solely on the metronome, letting the music unfold on its own terms? In *Sydney Polypulse*, I find it especially difficult to ignore the other musicians, likely because the repeated-note material brings the phasing relationships to the foreground. That was precisely my intention in this composition.

[47] The two voices of the 21:20 phase are at tempi 63 and 60 bpm.
Duration of a beat at 63 bpm: 60,000 milliseconds / 63 beats = 952.38 milliseconds/beat
Duration of a beat at 60 bpm: 60,000 milliseconds / 60 beats = 1,000 milliseconds/beat
Difference = 1,000 milliseconds - 952.38 milliseconds = 47.62 milliseconds
With each iteration (or beat), the relationship between the two voices will shift by 47.62 milliseconds.

Hartenberger identifies a number of related qualities:

> [...] the ambiguity in the music creates interest and the repetition can create a meditative state; but these qualities also require the player to develop heightened concentration in order to play the part correctly and still enjoy listening to the sound of the ensemble. (Hartenberger, 2016, p. 133)

At first, the texture can seem static, a mass of repeated notes. Given time, however, the timing relationships themselves come forward, and movement and contour become audible. This connects to a broader point in music cognition and aesthetics: perceived complexity is shaped not only by the intrinsic structure but also by the time allowed for it to unfold. Research on form, expectation, and processing time suggests that extended durations and repetition enable listeners, including performers, to perceive details that would be missed in shorter spans (Margulis, 2007; Huron, 2006). What first appears static gradually reveals a nested activity that propels the music forward.

Hartenberger's concept of "relaxed intensity" is especially apt here (Hartenberger, 2016, p. 134). One attends with vigilance but without strain, allowing the structure of the phase to emerge while maintaining tempo discipline.

In sum, the most reliable practice combines three elements. First, a clear internal mapping of the phase landmarks - departure, midpoint, and return - so the ear has defined targets. Second, an adaptive attentional profile that tightens around synchrony and loosens in the middle of the phase, opening space for ensemble listening. Third, restraint in expressive microtiming near salient points, or at least a shared understanding within the duo of who will shape and who will hold, ensuring that well-intended gestures do not collide. Within this framework, the "inner robot" is not an aesthetic of rigidity but a scaffolding that supports expressive listening and ensemble interplay.

4.5.9 Reflection on computers, expression and interactivity

As established, the difficulty for players to maintain slightly different tempi next to each other is formidable, and that affects the quality of performances. Given the rhythmic precision achieved by the computer in the fourth arrangement of *For Bob* for the MIDI-driven Fokker Organ, why not pursue that path further and utilize computers in crafting more polytempo works? The rhythms are beautiful, as can also be heard in all of the mock-up tests made in Finale throughout this chapter.

The issue for me with this approach is that it lacks the expressive nuances of live players. My experience as both performer and listener leads me to the belief that the metronome takes away one of our greatest expressive tools: microtiming, where musicians can push and pull their notes against each other, choosing to play on the front side or back side of the beat, depending on how they interpret the music at each moment. Rather than being metronomic inaccuracies, these kinds of actions can enhance the musical content of a performance.

Returning to the question of using computers, a fascinating development in some of today's popular music is the exploration of microtiming in DAWs, creating grooves which place notes distinctly outside of the rhythmic grid (Brøvig-Hanssen, Ragnhild, Aareskjold-Drecker & Danielsen, 2021). However, there is much more to live performance than just microtiming. I have tried to create compositional strategies that leave room for personal choice in other parameters of the music, such as articulations, dynamics, tone color, intonation, exact note lengths, and sound projection.

In my polytempo works, particularly in *Sydney Polypulse,* I have tried to find a way to marry the beauty of the rhythm with the expression of the live players and their interactions. In comparison to the large polytempo textures of *Building Music* and *For Bob*, a main goal of *Sydney Polypulse* was to explore interactivity between the individual players. While *Sydney Polypulse* is largely predetermined in pitch, rhythm, and form, it leaves much room for the ensemble to create its own interpretation of each section through individual choices. A player will have an idea to play a note a certain way and then the others can react to it. This is a possibility afforded by the haptic metronome: it leaves the ears available to listen. Thus, musicians can simultaneously maintain synchronization with their click tracks and attune to how the sounds blend in the space. While the polytempi driven by metronomes put the musicians in rhythmic handcuffs, the music still invites them to express their unique interpretations using the other variables. Players use these parameters to shape their performance, influenced by their own intentions and the performances of their fellow musicians. When executed well, synchronization emerges not from merely aligning notes in time, but from harmonizing musical approaches to the piece's interpretation.

The challenge in these polytempo pieces is not only to combine restriction with freedom, but rather freedom *within* restriction. While this paradox applies to nearly all notated music, it takes on a particular significance when the rigidity of clock time is introduced into live performance.

4.6 Conclusion

This chapter outlined my approaches to polytempo, weaving together analysis and conclusions, artistic intentions, practical experimentation, scientific literature, study of best practices, and interventions into my own methods to create works of music.

The chapter began by delving into a general theory of the rhythmic grid in practice. Through an analysis of its components, I created a new permutation of approaches to those elements. This conceptual framework allowed me to generalize about different kinds of polytempo and to propose structural strategies that may inspire new pathways for future compositions.

From there, the focus shifted to the sound of polytempo and the artistic motivations that shaped my own practice. The bulk of the chapter documented how I developed and refined these approaches across three works, through processes of experimentation, discovery, and intervention. By articulating these processes in detail, I aimed above all to clarify the compositional decisions that underlie my polytempo pieces, and to show how they emerge from concrete encounters with instruments, performers, and performance situations.

Several interrelated insights emerged over the course of the chapter. The basic rhythmic grid was shown to be a hierarchical structure of tuplets, beats, and bars through which monotemporal music is organized. Extending this concept into polytempo provided a new theoretical lens for understanding layered rhythmic systems, while the addition of expressive timing introduced a further, superposed grid. In chamber music, musicians continually coordinate both fundamental and expressive grids with one another. Polytempo places pressure on this coordination and, in doing so, opens up new performance practices and listening modes. The permutation of pulse, tuplet, and meter classifications was proposed as a practical tool through which composers can generate structural possibilities in this expanded temporal field.

The chapter also clarified two broad types of polytemporality: static configurations of fixed multiple tempi and dynamic configurations based on tempo modulation. This distinction helps both composers and analysts to frame polytempo strategies more precisely. Across the case studies, I showed how the synergy of concept and technique occurs at the earliest stages of composition, as creative ideas about layered time interact with practical issues such as the use of metronomes, spatial setups, and notational decisions. Attention to the upper and lower limits of tempi emerged as a defining factor in shaping musical character. These bounds are set not only by stylistic conventions but also by performers' physical capacities, emphasizing that the body itself draws important lines around what kinds of polytempo are feasible.

Further conclusions concern the ways in which polytempo is staged and supported in performance. Spatialization of instruments on stage plays a central role in how listeners perceive layered tempi, suggesting that decisions about placement and movement are not merely presentational but structural. Experiments with different kinds of metronomes led to the finding that haptic devices offer a particularly productive balance between rhythmic accuracy and the freedom to listen, a conclusion that is relevant not only to composers and performers but also to designers of future music performance tools. In addition, the discussion of tuplets and rhythmic figuration showed how speed in music cannot be reduced to tempo alone. Patterns of subdivision and density extend the range of perceived motion, offering broader palettes of speed, flow, and resistance for composers to work with.

Finally, the chapter reconsidered ensemble coordination under polytempo conditions. Synchronization was expanded to include the deliberate non-synchronization of sounds, reframing ensemble playing as the management of controlled asynchrony as much as the achievement of exact simultaneity. Subdivision strategies, repetitive motions, and attentional techniques were described as concrete methods through which performers can achieve accuracy in phasing while remaining musically engaged. Even when musicians aim for "computer-like" precision, the expressive qualities of live performance - microtiming, tone colour, interaction, and situated responsiveness - remain indispensable. Polytempo thus appears not only as a compositional technique but also as a performance practice that brings human and mechanical time into a productive and sometimes tense dialogue.

In sum, this chapter has contributed a conceptual framework, practical methods, and artistic reflections on polytempo. It can support composers in structuring polytempo works, performers in realizing them, teachers and students in developing rhythmic awareness and ensemble strategies, and music psychologists in studying how humans perceive and produce layered temporalities.

Chapter 5: Speed of Creation

Improvisation demonstrates complex and emergent properties that are greater than the sum of its parts.
(Cobussen, 2017, p. 175)

[C]omposing and improvising are not two distinct qualities; they are just different strategies of dealing with musical materials.
(Barrett, as cited in Cobussen, 2017, p. 190)

Should we not then speak perhaps of rapid and slow composition rather than of composition juxtaposed to improvisation?
(Nettl, 1974, p. 6)

There is much more going on on the recording, but this "going on" does not always translate into notes on paper.
(Jarrett, n.d.)

There are many ways of notating the same music.
(Corigliano, n.d.)

5.1 Introduction

Across this dissertation, I developed a situated account of musical speed through perceptual thresholds, density, and smooth and striated time, and I examined tuplets and polytempo as compositional tools for organizing pace and simultaneity. This final chapter turns from musical outcomes to the act of making them. Through a single case study, it argues that the speed at which the work is composed functions as a governing parameter that conditions what the music can become. It also claims that notatability shapes what can be retained, transmitted, and rearticulated by other performers.

The case study concerns *Torrent* (2011), a solo flute composition written for flutist Reiko Manabe. Rather than drafting and revising, I based the work on an improvisation played at my highest sustainable speed while still being able to retain a measure of choice in the unfolding material. The plan was simple and strict: no rehearsal or advance preparation of harmonic, melodic, textural or formal materials; the sole aim was to play as many notes as possible without resorting to repetition. The recorded take served as the compositional source, and the subsequent transcription was governed by a rule of minimal intervention. By refusing to improve, correct or recompose the material after the fact, I kept compositional risk inside the act of fast making itself. The procedure tests how musical decisions change when they must be made in real time and cannot be redeemed later through revision, and how those irreversible conditions shape what the piece becomes.

This approach positions *Torrent* at the intersection of improvisation and composition, with speed functioning as the operative condition that binds them. Material and form arose through continuous, time-pressured decision making in its performance, drawing on embodied know-how under pressure and was later fixed and made transferable through transcription. Speed is therefore treated here as causal and formative rather than descriptive. It forces decisions into the sounding present, draws material from embodied technique, and organizes form through the affordances and limits of what can be steered at pace. The score provisionally fixes that outcome as a transferable text, but it also transforms the event by translating an embodied, high-speed ecology into a set of graphic instructions that remain interpretable and executable by another body. The chapter first clarifies the procedural constraints and the listening stakes of the recording, then examines what the transcription preserves and what it transforms when the event is made transferable. It then considers how two performers, Reiko Manabe and Kenneth Cox, interpret and re-articulated the work in performance.

Example 5.1. *Torrent*, score excerpt.

Example 5.2. [*Torrent* improvisation](), audio.

5.2 Improvisation, Fixation, and Transfer

This section situates *Torrent*'s procedure within longer histories of traffic between improvisatory practices and notated texts. It then uses three contemporary comparison cases to clarify what is gained, lost, and reallocated when a singular event is made repeatable through recording and notation.

Improvisations and notated compositions have been entangled throughout Western musical practice. Baroque and Classical fantasias preserve an extemporizing stance within notation, as in Bach's *Chromatic Fantasia*, Mozart's C minor *Fantasia* K. 475, and Beethoven's Op. 77. The nineteenth and twentieth centuries offer further cases in which improvisation is integrated into composed texts, from Liszt's written paraphrases and cadenzas to works such as Gershwin's *Rhapsody in Blue* (1924), whose signature opening clarinet glissando began as a rehearsal improvisation and was subsequently absorbed into the work's fixed musical text (Farrington, n.d.). In jazz, rapid improvisation has generated bodies of material that entered notated and analytic domains through transcription, most notably in the music of Charlie Parker and John Coltrane, whose solos circulate both as recordings and as detailed scores, for instance in collections such as the *Charlie Parker Omnibook* and published transcriptions of Coltrane's solos from works like *Giant Steps* and *Countdown*.

A different but related trajectory is the later fixation of improvisation through notation, including the organ tradition of recording and transcribing concert improvisations. This lineage reaches from the long-standing practice of organ improvisation in and around the time of J. S. Bach to the twentieth century practice of recording and transcribing concert improvisations, as in Maurice Duruflé's note for note editions of Tournemire and Vierne's improvisations, Olivier Latry's *Salve Regina*, which began as improvised commentary and was later realized as a fully notated work, and Olivier Messiaen's *Messe de la Pentecôte* (1950), explicitly based on his own organ improvisations. Aesthetics scholar Katya Davisson (2022, p. 377) points to some of Giacinto Scelsi's works as another exemplar of improvisation used as a compositional method, in that his improvisations were recorded with the intention of later transcription and publication.

Despite this history of entanglement, the hierarchy that privileges the score and the composer as the primary creative agents, reducing the performer's role to the reproduction or execution of an "ideal object" (Schuiling, 2016, p. 43), is comparatively recent. Scholars Bruce Ellis Benson and Marcel Cobussen challenge this hierarchy by insisting that performance is always also a form of improvisatory work, because performers cannot simply reproduce what is "there" but continually rework a notated text in sound (Benson, 2003, pp. 23–30; Cobussen, 2017, pp. 31–33). Schuiling, drawing on Nicholas Cook and Bruno Nettl, frames the same point in process terms: music persists between process and product, and any product is best understood as a temporarily petrified moment within an ongoing unfolding that is provisionally frozen in a given performance (Schuiling, 2022, p. 323).

For the present chapter, the crucial issue is what changes when an improvisation is deliberately routed into fixation and transfer. Davisson argues that some improvisations become compositions as fixed, repeatable works when they are solidified through recording and notation, because notation enables the event to be separated from its original performance and learned and performed by others (Davisson, 2022). Seen through the chain of mediations that links improvisation, recording, and score, the score of *Torrent* is strictly speaking not a transparent duplication of an improvisation, but a representation of an already fixed artefact. The recording provides a first fixation, preserving the event as a continuous temporal trace that remains available for repeated listening. Transcription then performs a further act of entextualization, because it passes that trace through the categorical grammar of staff notation. Timing must be discretized into notatable units, rhythmic groupings must be selected, and some parameters must be foregrounded while others remain underspecified. Microtiming, timbral nuance, and fine-grained transitions, for example, are often simplified, redistributed or displaced into performance instructions rather than captured directly. At the same time, this second fixation produces a new affordance, because it renders the event iterable for another performer and relocates agency into the interpretive work of re-performance.

Against this backdrop, it is helpful to consider three recent comparison cases that follow related trajectories from improvisation to fixed score. John Corigliano's *Winging It* (2008) began from recorded piano improvisations and was then transferred into staff notation with MIDI capture and editorial assistance (Corigliano, 2008). Crucially, Corigliano frames the score not as an exact documentary trace but as a practical stabilization of what the improvisations were "meant to do." In his account, passages that were intended to recur were sometimes standardized by copying material in the notation, rapid ascending runs were regularized where literal transfer would be unplayable or non-repeatable, and one movement was structurally adjusted by repeating an opening section and adding a short composed ending. *Winging It* therefore exemplifies a hybrid logic of fixation: improvisation supplied the source material, while post-improvisational editing re-introduced revision latitude in the service of repeatability and performative feasibility. This makes it an instructive comparison point for *Torrent*, where the governing rule was as much faithfulness as possible to a single recorded take without post-hoc redesign.

Keith Jarrett's *The Köln Concert* (1975) offers a closely related example of an improvisation later transcribed with the explicit aim of staying close to the recording rather than revising it. Jarrett's preface positions the improvised performance as the primary work and treats the later notation as ontologically derivative. He permits transcription only because the recording has already fixed the event in a permanent medium, and he implies a hierarchy of authority in which the score can approximate and enable re-performance, but the recording remains the decisive reference (Jarrett, 1991 [1975]).

Giacinto Scelsi's published works provide a third and more radically mediated case of improvisation routed into notation. In the 1950s and later, Scelsi's working method centered on extemporaneous improvisation, often on the ondiola[48] in tape-recorded sessions that were later transcribed by collaborators and then published (Fusi, 2020, p. 55). As violinist and researcher Marco Fusi argues, because Scelsi distanced himself from what he understood as conventional composing, assistants were repeatedly required to decide how the tape material should be turned into a playable score (Fusi, 2022, pp. 85-87). In the case of the violin divertimenti, the composer Vieri Tosatti did not only document the tape traces; he also adapted them in line with his own late romantic conception of violin techniques and sound, effectively reworking aspects of the recorded material in the act of transcription (Fusi, 2022, p. 87). This delegated passage from tape to notation differentiates Scelsi from Jarrett, who personally oversaw the published transcription and authorized it, stressing that he had overseen every step and almost every note of the final result, and from Corigliano and myself, where the composer directly produced and authorized the notated text.

Placed beside Corigliano and Jarrett, Scelsi's approach clarifies that fixation is not a single operation but a string of mediations that redistribute agency. Corigliano actively regularized and edited his improvisations to produce a playable, repeatable score. Jarrett authorized the published transcription only after the recording had secured the event, and only after he personally oversaw every step and almost every note of the final transcription process (Jarrett, 1991 [1975]). Scelsi, by contrast, delegated the passage from tape to score and in doing so allowed the transcriber's technique, culture, and aesthetic assumptions to enter the notated result (Fusi, 2022, pp. 85–88). Considered together, these cases show that a score is never a neutral duplicate of an improvisation. It is a negotiated transfer that stabilizes some parameters for re-performance while leaving others to be reconstructed.

[48] The ondiola is an early, French-developed electronic analog synthesizer from the 1940s.

5.3 *Torrent* Examined More Closely

Building on the three comparison cases in the previous section, I turn to *Torrent* as my central case study for how speed shapes musical creation. I am not primarily concerned with defining improvisation against composition, but with how speed redistributes musical decision making and fixation across real time and deferred time. The next section introduces a figure that maps practices by creation speed and reflective latitude and provides a compact comparative frame for discussing how different practices allocate decision time, revision, and fixation. I then apply this framework to *Torrent* through four lenses: improvisation as the methodological frame for generating the material; tactile processes and embodied control parameters; chunking and real time decision making; and flow and temporal integration under pressure. The final sections address notation, re-performance, and interpretive space, examining how the improvisation's smooth temporal behavior confronts the affordances and constraints of Western notation, how the score entextualizes the recorded event, and how Manabe's performance reveals the interaction between notation, embodiment, and interpretive agency.

5.4 Speed of Creation: A Map of Approaches by Speed and Reflective Latitude

5.4.1 From Torrent's hinge to a speed-based reframing

Section 5.2 established *Torrent*'s specific hinge: a real-time improvisation undertaken under the prior constraint of later fixation and re-performance. *Torrent's* distinguishing feature in this comparison is sustained maximal velocity, combined with a prior commitment to transcribe the take as faithfully as possible, without later redesign. That combination makes the pace of decision-making, and the reflective latitude available before commitments become effectively irreversible, the most salient analytic dimension for what follows.

Against these different fixation logics, the variable I foreground is the pace of decision-making in the source event. For comparison, Corigliano's *Winging It* and Jarrett's *The Köln Concert* unfold over much longer spans and traverse a wide range of surface velocities rather than sustaining a single maximal event rate. By contrast, *Torrent* compresses its compositional work into a single four to five minute improvisation that maintains a near continuous high velocity event flow. Coupled with the prior constraint of exact transcription without post-hoc redesign, this procedure placed unusual pressure on my moment to moment attention, because each local decision immediately narrowed the range of viable next moves and could not be retrospectively refined. Rather than treating labels such as improvisation and composition as the primary explanatory terms, I foreground the tempo of decision-making itself: how quickly choices must be made, how far they can be revised, and how those choices become fixed for later transfer. Bruno Nettl's provocation, "should we not then speak perhaps of rapid and slow composition rather than of composition juxtaposed to improvisation?" (Nettl, 1974, p. 6), sharpens this shift of focus. This motivates Figure 5.1, which provides a compact comparative frame for discussing how different practices allocate decision time, revision, and fixation. It maps creation practices by creation speed and reflective latitude, and it allows *Torrent's* real-time generation and deferred-time transcription to be discussed within a single field.

5.4.2. Figure 5.1 as a heuristic map

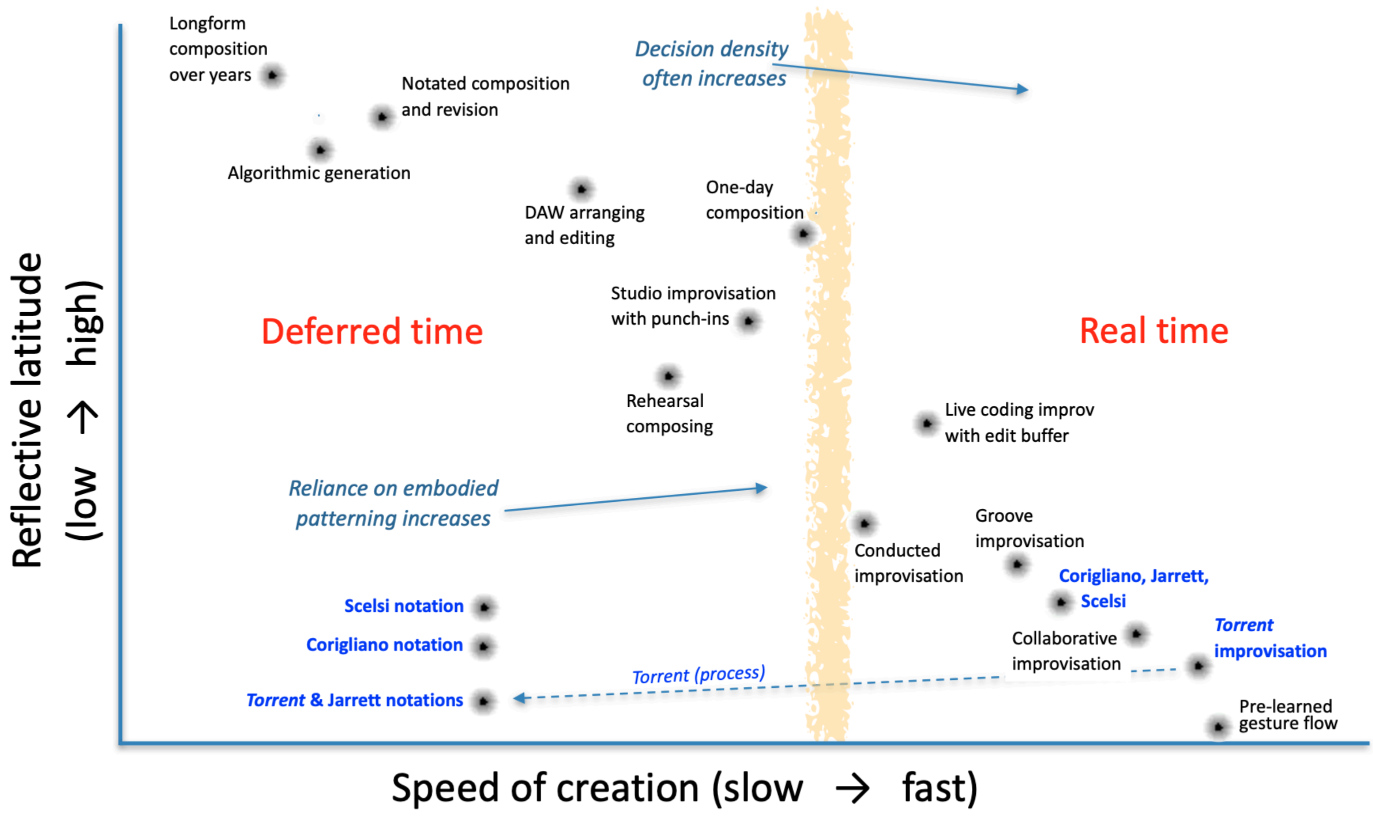


Figure 5.1. Speed of creation. Positions are indicative rather than definitive; the boundary between the real-time and deferred-time regions is porous, and a single work may traverse the map across phases.

Figure 5.1 maps creation practices along two axes: creation speed on the horizontal and reflective latitude on the vertical. It treats creation not through a binary of improvisation versus composition, but as a set of decision making situations that differ in how quickly choices must be made, how far they can be revised, and how creation time relates to sounding time. By placing deferred time workflows and real-time emergence in the same field, the figure operationalizes Nettl's shift toward thinking in terms of faster and slower creation, while keeping the reduction explicit.

5.4.3. Temporal modes and how speed operates

Across this spectrum, I distinguish two broad modes of creation. In deferred-time creation, decisions may be distributed across sessions and supported by notation, recordings, software, and collaborators, which allows creators to pause, branch, revise, and reorganize materials nonlinearly. Many revision-rich workflows such as notated composition, arranging, and digital editing are typical of this mode. In real-time creation, by contrast, perception, action, and rapid appraisal are tightly coupled within the sounding present, with limited backtracking, so decision pressure increases reliance on embodied schemata, entrainment, and microtiming. On this basis, Figure 5.1 clarifies that "speed of creation" means something different in each temporal mode. In deferred time it concerns workflow nonlinearity, while in real time it becomes inseparable from the pace of the material in the sounding present.

These distinctions also clarify how the figure can be used to compare creation processes discussed elsewhere in the dissertation, without requiring each work to be plotted in detail. The next sections apply these definitions by reading Figure 5.1 comparatively and by locating *Torrent*'s two phases within the map, including what counts as reflection when decision windows become very short.

5.4.4. Reflective latitude and the action-present

With these temporal-mode distinctions in place, organizational theorist and scholar of professional practice Donald Schön's notion of the action-present helps specify what counts as reflective latitude when decision windows become extremely short. Schön's account is a useful conceptual parallel for Figure 5.1 because it foregrounds how the pace and temporal boundaries of an activity shape what kinds of reflection and revision are possible within it (Schön, 1983, p. 77). Schön argues that a prevailing account of expertise overemphasizes methodical control and underemphasizes the situated, emergent work by which practitioners define, adjust, and sometimes replace their aims as the situation develops (Schön, 1983, p. 31). Within musical creation, a comparable bias appears when control is located primarily in explicit techniques and stabilized artefacts, and when the situated work of determining what counts as the task is treated as secondary. In *Torrent*, that task-setting included deciding in the moment how to balance continuity of flow, avoidance of repetition, and the distribution of attention across micro, meso, and macro timescales[49] under maximal speed. Schön's corrective is to foreground problem finding and problem setting, which he argues "has no place" in a body of professional knowledge concerned exclusively with problem solving (Schön, 1983, p. 29). In *Torrent*, this meant that, alongside solving local technical problems, I had to keep re-posing the compositional problem in real time: how to sustain maximal velocity without repetition, where to pivot register and note choices, and how to pace breath and materials across different timescales.

The horizontal axis, creation speed, correlates with Schön's "action-present," the temporal window within which action can still redirect an unfolding situation, and whose duration depends on "the pace of activity and the situational boundaries" of a practice, ranging from seconds in fast interactive episodes to months in extended cases (Schön, 1983, p. 77). Schön is explicit that even a brief action-present need not exclude reflection, citing performers who learn to insert "a moment to plan" within split second exchanges and to integrate such reflection into the smooth flow of action (Schön, 1983, p. 324).

The vertical axis is therefore described here as reflective latitude, a term not used by Schön but introduced to name the degree to which a creation situation affords opportunities for reflection-in-action, whether as rapid re-appreciations or as expanded, reversible sequences of trial and revision in constructed virtual worlds (Schön, 1983, pp. 186, 324). This avoids equating low latitude with diminished cognition, since Schön's knowing-in-action includes judgments of quality and skilled discriminations that practitioners cannot fully state as rules or criteria (Schön, 1983, pp. 63–64), and it clarifies why instrumental constraints matter, because practice unfolds as a conversational process in which the situation "talks back" and redirects subsequent moves (Schön, 1983, p. 93).

What the mapping in Figure 5.1 adds for the case of *Torrent* is an explicit coupling of creation time and sounding time, and a way to show how a single work traverses these coordinates. In *Torrent*, this coupling is materially anchored in a single source recording, which functions not merely as documentation but as a first fixation of the improvisational event. Davisson (2022) notes that recording can satisfy a work's repeatability condition by providing a stable basis from which later performances can be formed. The later score constitutes a second fixation, translating that fixed trace into the discretizing affordances of staff notation for the purpose of re-performance.

[49] explored further in 5.6

5.4.5. Reading Figure 5.1: reduction, boundaries, and traversal

As with any scheme, Figure 5.1 should be read as a situated reduction rather than a comprehensive model of a creative practice. It foregrounds a single analytic dimension, namely the temporal distribution of decision-making, and shows how this distribution conditions what kinds of reflection, bodily know-how, and fixation can occur. The axes therefore do not exhaust the phenomenon, and the boundary between regions remains permeable: practices slide, overlap, and shift as conditions change.

Torrent is plotted twice because its making unfolds in two distinct temporal modes. The source improvisation occupies the high-speed, low-latitude region. Decisions are made in the sounding present, with reliance on practised motor schemata and embodied timing, yet with ongoing moment-to-moment steering under pressure. The transcription phase occupies the deferred-time region. Creation becomes slow and distributed across sessions, but reflective latitude remains constrained by the rule of exact transfer, so decisions concern legibility and representational accuracy rather than redesign. For orientation, the figure also marks an extreme within the real-time mode: pre-learned gesture flow, where automatized figurations can be streamed at very high speed with minimal re-appreciation beyond rapid selection and reshuffling.

The map also places *The Köln Concert* and *Winging It* across real-time generation and deferred-time fixation. Like *Torrent*, both projects sought to preserve the improvisation as faithfully as possible in notation, which keeps their notational outcomes relatively low on the axis of reflective latitude. However, *Winging It* incorporates selective editorial adjustments for playability, which places it somewhat higher on that axis than either *Torrent* or the authorized *Köln Concert* transcription. Scelsi's tape-based practice adds a third configuration: real-time generation followed by deferred-time fixation in which reflective latitude increases because transcription entails substantive interpretive and idiomatic decisions by assistants, rather than strict transfer.

With the axes now defined, Figure 5.1 can be used comparatively across the other compositional cases discussed in this dissertation. A composition derived from a slower improvisation would fall to the left of *Torrent* within the real-time region, with more reflective latitude because the action-present is longer. The other works from my hand discussed in this dissertation fall within the deferred-time region, in the "notated composition and revision" zone, including those composed over days, weeks, or months. They differ primarily by degree of workflow nonlinearity and revision affordance, meaning how far the process can be suspended, revisited, and resequenced. In this sense, *Torrent* functions here as a boundary case that makes the variables legible by compressing the action-present near its practical limit and clarifying how later fixation redistributes agency under a different temporal mode.

5.4.6 Actants and operational parameters

Cobussen emphasizes that improvisation never happens in isolation, and that each event unfolds within a "unique constellation of various actants," both human and nonhuman (Cobussen, 2017, p. 94). This observation matters here because Figure 5.1 tracks only one dimension of that ecology, namely how decision windows and opportunities for revision are distributed in time. *Torrent* offers a deliberately constrained instance: the source improvisation concentrates agency in a particular constellation of body, instrument, room, and recording setup, and its high speed compresses reflective latitude within the sounding present. The later transcription then re-enters the same event under a different constellation, in which the recording, staff notation, and layout decisions become active constraints oriented toward a bounded fidelity to the recording, within the parameters the notation can carry.

Operationally, the map can be specified through four parameters that describe how decision episodes are distributed and stabilized. First, the temporal mode asks whether choices are made within the sounding present or across deferred sessions. Second, the workflow linearity concerns whether the process proceeds in a single forward pass or can be suspended, branched, and resequenced. Third, the revision affordance addresses how easily decisions can be reopened, ranging from largely nonrevisable real-time commitments to iterative comparison and replacement in deferred time. Fourth, actants refers to the human and nonhuman participants that shape decision flows (Latour, 2005; Cobussen, 2017). In real time these often include body, instrument, room, audience, and microphone or recorder; in deferred time they often include recording media, notational systems, digital audio workstations, versioning tools, and page layout. The point is not to catalogue every influence, but to make explicit which constraints and affordances are doing the work in a given phase.

Figure 5.1 also foregrounds embodied and tacit know-how that is sociohistorically situated. Even at the far right of the map, real-time choices are saturated by deferred-time resources, including technique, repertoire, instrument specific habits, listening histories, and stylistic expectations. As decision time contracts, bodily technique, mimetic motor imagery, entrained gesture patterns, and historically conditioned idioms and expectations tend to dominate. As decision time expands, reflective comparison, tooling, iteration, and explicit stylistic choice can become more prominent.

In this sense, when I refer to learned patterns, I do not mean only scales, arpeggios, intervals, and other familiar licks. I also mean the foundational embodied competencies that underpin instrumental practice: how the flute is held and blown, the air pressure regimes required for different dynamics and timbral qualities, and the fine grained motor adjustments involved in tone production. These capacities are not timeless. They are cultivated within historically specific technique cultures, instrument designs, listening histories, and aesthetic norms, which condition what counts as playable, intelligible or desirable in the first place. For example, difficult or more fluid fingering combinations exert a substantive and often determining influence on the resulting music.

5.4.7 Implications for Torrent

Several implications follow. When decisions must be taken in rapid succession, creators allocate limited predictive bandwidth by drawing on learned schemata that are simultaneously embodied and sociohistorical, including tactile routines, gesture-level structures, and culturally learned idioms and expectations. This economy of attention is not value neutral: it is shaped by stylistic, historical, geographical, aesthetic, and ethical frames that define what counts as viable or desirable in the moment. Deferred-time processes retain embodiment while expanding reflective latitude through externalization and nonlinear iteration. Decisions remain constrained by bodily skill, instrument affordances, and relatively stable learned expectations, but iteration permits search, comparison, and reordering of materials. Attentional limits also set practical ceilings for the fastest reliable novelty. Beyond these limits, creators either narrow the range of viable next actions or increase reliance on routinized priors through reinforced entrainment. In *Torrent*, the source improvisation sits close to this limit: speed presses against physiological and cognitive thresholds while still preserving moment-to-moment steering within the sounding present. The outcome reflects a particular balance of constraint and agency, sustained through both overlearned control and ongoing selection and recombination in real time.

Torrent therefore serves as a focused case for observing how speed, embodiment, workflow linearity, revision affordance, and actants co-produce musical material, and how creation time conditions sounding time. It also clarifies that real-time creation is not a single regime: even within the sounding present, decision windows vary in duration and afford different degrees of rapid re-appreciation. Schön's injunction to give a central place to the ways practitioners create opportunities for reflection-in-action captures this point: in musical terms, such opportunities often arise at breath points, gesture segmentations, and chunk boundaries, where a fraction of a second can be reclaimed for steering what comes next (Schön, 1983, p. 324).

The remainder of this chapter investigates the creative process of *Torrent* in greater depth, examining the work's engagement with free improvisation, tactile processes, chunking, flow, and notation, and how these dimensions of the speed of creation coalesce within the piece.

5.5 Free Improvisation: Tensions and Function

While creating *Torrent*, the aim was to generate a coherent, maximally rapid musical flow in real time. Although the temporal density of *Torrent* is not maximal in absolute terms, it enacts the perceptual mechanisms discussed in Chapter 2. When pulse, phrase regularity, harmonic rhythm, and metric scaffolding do not provide periodic reference points, speed can register as urgency because periodic anchors are withheld and events remain continuously recontextualized. Continuous alternation among arpeggios, scale fragments, and abrupt registral shifts keeps materials from settling into recognizable units, so that even a single melodic line is experienced as highly kinetic and volatile. These perceptual effects are one reason free improvisation matters for the creation of *Torrent*. A second reason is methodological: free improvisation foregrounds the mechanism of material choice because decision and execution can coincide. When no preselected materials or formal paths are fixed in advance, selection becomes more audible. At the performer's limit, choice operates as rapid recruitment, recombination, and inhibition of overlearned patterns, including gesture vocabularies, fingering routes, articulatory routines, and timbral habits. This attempt to suspend stylistic precommitments also raises a terminological question about idiom.

In those terms, the approach might initially seem aligned with guitarist and improviser Derek Bailey's concept of "non-idiomatic improvisation," which describes improvisation that neither emerges from nor adheres to established stylistic norms (Bailey, 1992, pp. xi–xii). Yet the category is unstable. Scholars such as improviser and composer George Lewis and philosopher-musician Gary Peters show that practices that seek to avoid idiom can consolidate into identifiable patterns through repeated strategies, producing what could be called an idiom of non-idiomaticism (Lewis, 2004, pp. 104–107; Peters, 2009, pp. 79–82). Peters also cites Pierre Boulez's critique that free improvisation often defaults to predictable elements, for example repeated notes or notes separated by long silences (Boulez, as cited in Peters, 2009, p. 82). For these reasons, it is more precise to situate *Torrent* within Richard Barrett's account of free improvisation, in which the performer remains open to any possibility and refuses prior commitment either to adhere to or to reject references to existing musics and materials, while the structural framework is brought into being at the time of performance (Barrett, 2019, pp. 44, 48). Barrett's formulation also makes room for the practical fact that references can be avoided, tolerated or embraced as the performance unfolds, rather than prohibited in advance.

This openness doesn't imply the absence of constraints. In practice, the working method involved deliberate refusals of a clear pulse, regular rhythmic patterning, tonal signalling, slow melodic phrasing, and conventional formal markers such as cadences, grooves, and ostinati. However, the fact that these elements can be named in advance indicates how strongly they normally organize musical making, and how working *against* them remains a way of working *with* them. At the speeds pursued here, invention is bounded by what has already been sedimented as technique, expectation, and habit, including overlearned control of articulation, breath, fingering routes, and registral stability. *Torrent* therefore uses free improvisation as a methodological tool for investigating how extreme speed compresses choices in the present tense of performance, in which embodied patterns both enable and constrain what can be steered in real time. Its sonic vocabulary is shaped by bodily limits, instrumental affordances, culturally learned expectations, and the immediate acoustical and performative situation.

5.6 Tactile Processes and Control Parameters

Building on the speed of creation figure discussed above, in which faster creation speeds shift a greater share of decision-making onto learned bodily schemata and tactile routines, this section examines how those embodied processes shaped the real-time formation of *Torrent*.

Sociologist and jazz pianist David Sudnow emphasizes that physical configurations and hand postures fundamentally shape improvisational choices and that tactile feedback is central to musical creativity (Sudnow, 1978, pp. 9–12, 73–74). In flute playing, this tactile work involves an embodied familiarity with the instrument's physical landscape - the precise feel of the keys, their subtle pressure points, and the exact hand and flute configurations required for notes and articulations. Just as a pianist develops particular tactile "ways of the hand" to navigate the keyboard, a flutist similarly acquires a "wayful traverse" through tactile familiarity, enabling nuanced control over pitch, intonation, and timbral modulation - specific challenges unique to wind instruments, as described by psychologist John Sloboda (Sloboda, 1985). Yet this very familiarity also functions as a double-edged sword: it opens possibilities to explore new terrains, while simultaneously disciplining the body in specific ways that can obstruct alternative modes of playing. For example, I might intentionally avoid certain intervallic or arpeggiated combinations if their fingering layouts create unnecessary resistance, since these physically awkward configurations become impractical at high speed and therefore shape which musical gestures emerge in real time.

In creating *Torrent*, my tactile approach drew heavily on motoric feel, with intervallic seconds and thirds playing a salient role in shaping the pitch relationships that emerged. Rather than stabilizing into repeated patterns, pitch sets were dynamically varied and displaced before they could congeal into recognizable motifs, while breath length directly influenced phrasing.[50]

Example 5.3. *Torrent*, opening phrase, audio excerpt.

This continual creation occasionally yielded unpredictable melodic contours, prompting further exploration. Composer and cognitive scientist Jeff Pressing describes one model of real-time adaptation as the immediate correction of potential "wrong-note" errors (1984, p. 354). Within the free improvisation

[50] Because these relations are calibrated to my own bodily habits, they do not transfer straightforwardly into another performer's sensorimotor repertoire. The consequences of this calibration for reperformance and interpretive space are taken up in section 5.9.

context outlined earlier, the category of error needs to be reframed, because correctness is not specified in advance. The activity compels continuation with whatever arises. Unexpected outcomes therefore become material to be absorbed rather than mistakes to be erased, a stance often paraphrased as "if you play a wrong note, play it again." Schön's notion of reflection-in-action aligns with this approach: surprise becomes a trigger for rapid, situated reflection that folds unforeseen events back into the evolving musical logic (Schön, 1983, p. 69-70).

As outlined in section 5.5, free improvisation does not eliminate criteria so much as relocate them into the moment of performance, where coherence, control, and direction are judged in real time. In *Torrent*, the operative criteria were concrete and explicit, including maximal sustainable speed, avoidance of repetition, continuity of flow, and the maintenance of a coherent energetic trajectory. That the first two takes were abandoned and the third retained indicates that these criteria were not yet met in the initial attempts. In a high-speed case such as *Torrent*, evaluation and redirection must occur almost instantaneously, which makes reflection in action a functional requirement for sustaining momentum and coherence.

These rapid evaluations also operated across what Godøy describes as micro, meso, and macro timescales (Godøy & Leman, 2010, p. 121). At the micro scale, each note involves finely tuned sensory–motor adjustments, including embouchure changes, finger movements, and rapid evaluations of intonation and articulation. At the meso scale, short groups of notes, motifs, cells, or gestural fragments are shaped in real time, providing local coherence and enabling moment-to-moment variation. At the macro scale, I maintained an overarching sense of trajectory, including how energy accumulates or dissipates and how larger-form decisions unfold. Crucially, every note in *Torrent* is situated across all three scales at once: each sounding event is a physical action, a local structural unit, and a contributor to the emerging large-scale form. In practice, attention oscillated between these scales under temporal compression, which is one way the improvisation remained steerable without becoming deliberative. This corresponds to what Cobussen calls thinking-in-and-as-action, an action–perception loop in which thought does not precede performance but unfolds within it as bodily action, perception, and environment become tightly coupled (Cobussen, 2017, p. 180). Pressing's framework further clarifies this ecology, because his figure diagrams major factors that steer improvised musical behavior.

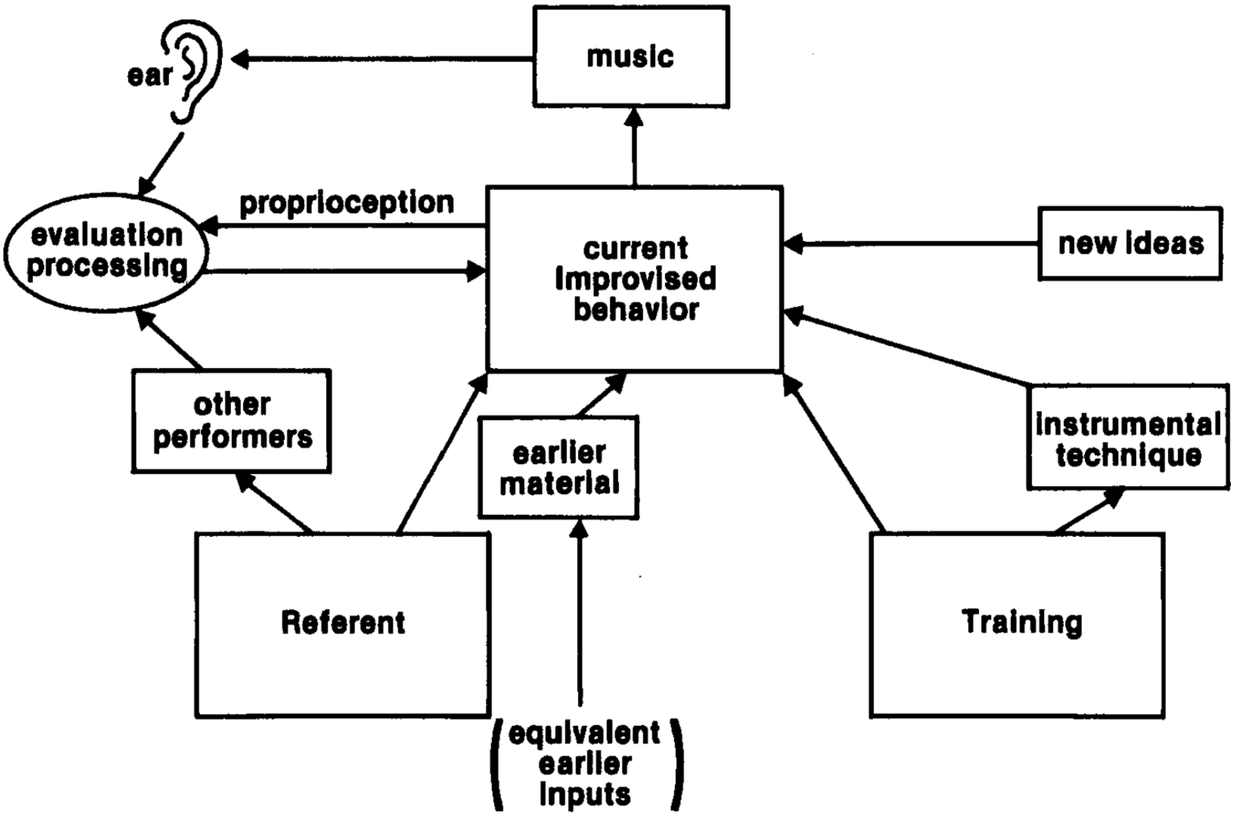


Figure 5.2: Major factors influencing the production of improvised musical behavior (Pressing, 1984, p. 352). In Pressing's figure, "referent" refers to a style or idiom, as discussed in section 4.5 above.

This continuous adaptive process enabled implicit formal decisions and sustained coherence amid the immediacy of tactile concentration (Sloboda, 1985, pp. 104–117). For example, the end of the initial phrase introduces a four-note cell (C♯, B, G, E) that becomes the basis for variations in the subsequent passage.

Example 5.4. *Torrent*, from bar 13, score excerpt. Audio excerpt.

Breathing also played a role in facilitating reflection-in-action. The variations derived from the four-note cell were likely conceived during the breath following those notes. Another notable breathing moment occurs near the end of the piece: after several minutes of continuous invention, I arrive at a double trill extended through circular breathing. This brief suspension in breath-based phrasing provided a final reflective moment that shaped my sense of how to conclude the piece.

Example 5.5. *Torrent*, from bar 58, score excerpt. Audio excerpt.

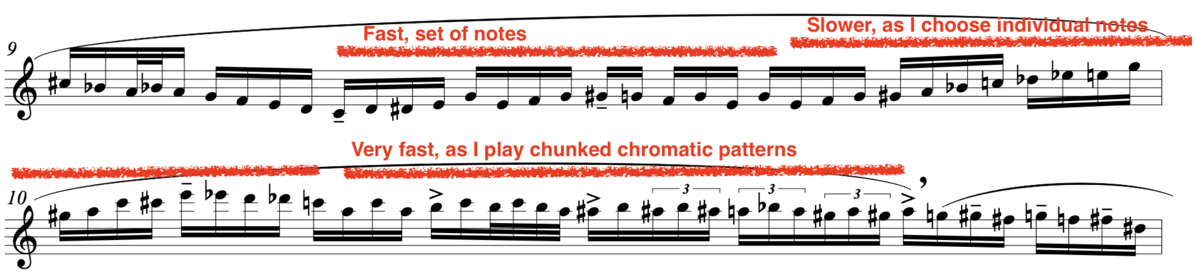
5.7 Navigating Speed Through Chunking and Real-time Decision-making

At the speeds sustained in creating *Torrent*, decision windows contract to the point where note-by-note steering becomes unreliable. Pressing (1984) estimates that the lower limit for corrective feedback in continuous tasks is approximately 100 milliseconds (Pressing, 1984, p. 354). In my performance of *Torrent*, playing at approximately 110 milliseconds per note (around nine notes per second) placed me close to this threshold. Under these conditions, continuity is more feasibly sustained by deploying pre-learned units and making decisions at their boundaries rather than attempting fine-grained correction at every event. One practical way to maintain continuity while still preserving moments of choice is therefore to shift decision-making from individual notes to meso-level units, using the technique of chunking.

The theory of chunking, elaborated by cognitive psychologists William Chase and Herbert Simon (1973) and applied to music by Sloboda (1985), suggests that complex sequences are stored in one's memory and executed as single perceptual units. Here, "chunks" refers to meso-level groups rather than the micro-level competencies required to produce an individual note. In *Torrent*, these units included scale fragments, arpeggiated figures, and gestural templates developed through extensive practice. Chunking therefore increases fluency, but it also narrows the decision window by temporarily committing the performer to the internal logic of the launched unit.

Chunks served two related functions. First, they enabled higher velocity by reducing the number of decisions required per note. Second, as the available motor fluency exceeded the tempo I was actually sustaining, chunking created brief "surplus" moments in which I could anticipate and select the next action. Given the dual aims in *Torrent* of sustaining very high speed while still shaping the line through choice, I continually shifted between exploiting chunks for acceleration and using them to open planning spaces.

Crucially, these units were not executed as fixed formulas. They were continually modified in response to tactile feedback, breath constraints, and the unfolding phrase logic. A simple example is the midstream transposition of an arpeggio, which combines a familiar chunk with an explicit decision to vary pitch content. In this way, chunking functioned not only as a mechanism of rapid execution but also as a means of keeping variation and steering active under temporal compression. *Torrent* therefore emerges from a dynamic interplay between automatized motor sequences and moment-to-moment steering within the sounding present, an interplay that can be heard throughout the recording.



Example 5.6. *Torrent*, from bar 9, score excerpt. Audio excerpt.

5.8 Flow, Temporal Integration, and the Improviser's Mindset

The complex interplay between automated motor sequences and real-time reflective steering also directly relates to the multi-layered state of flow. This phenomenon has been extensively explored in scholarly literature, particularly in the work of psychologist Mihaly Csikszentmihalyi (1990) and cognitive neuroscientist Arne Dietrich (2004), who define flow as a state of immersion where action and awareness merge, typically characterized by automaticity and diminished self-awareness. My experience of flow in *Torrent*, however, diverged significantly from this common understanding. Performing close to my physiological speed limits sharpened rather than diminished my attention. What emerged was not a detached evaluative stance, but an intensified coupling of listening, steering, and execution. I do not suggest that mental processes act independently of bodily responses. Instead, I experienced a continuous negotiation between intuitive sensorimotor responsiveness and active attentional oversight.

This negotiation resulted in a complex, layered awareness encompassing retrospective reflection, real-time adjustment, and anticipatory planning, as shown in Figure 5.2. In the sounding present, I found myself drawing on phrases internalized through years of practice, including fingerings, melodic fragments, and arpeggiated flourishes. Pressing's concept of perceptual traces, meaning brief sensorimotor residues that remain available to guide subsequent action, helps articulate how just-played gestures immediately inform what follows (Pressing, 1988). These traces support active listening to the unfolding line and provide local cues that shape the next musical turn.

Prospectively, my awareness moved between deciding the next notes, shaping phrase trajectories, and tracking emergent formal development across micro, meso, and macro timescales. This orientation was driven by tactile considerations, the timing of the next breath, and an unfolding musical logic, understood as coherence measured against learned expectations and prior musical experience. Neuroscientific studies indicate that entering a flow state typically involves downregulation of the lateral prefrontal cortex, associated with self-monitoring (Limb & Braun, 2008). Although this might appear to contradict my emphasis on heightened conscious monitoring, my experience reflects an expanded and refined understanding of what conscious monitoring entails - less about evaluative judgment and more about intense, dynamic engagement with continuous creative output.

One additional factor intensified this state, namely the knowledge that the take would be fixed and later re-performed. This added compositional pressure to maintain continuity while keeping the emerging material transferable.[51] This pressure corresponds with ethnomusicologist Paul Berliner's concept of the psychological edge, where performing slightly beyond one's comfort zone heightens cognitive and creative engagement (Berliner 1994, p. 269). Operating within this zone demands constant adaptability, responsiveness to unexpected events, and rapid decision making. In *Torrent*, the inherent tension between control and automaticity sharpened my focus, intensifying the richness of my immediate experience, and reinforcing the complex, layered awareness that characterized my improvisational flow.

[51] Questions of what can be stabilized in notation, and what remains dependent on tacit reconstruction from score and recording, become explicit in Section 5.9.

5.9 Notation, Reperformance, and Interpretive Space

The final facet of this case study is notatability, meaning the extent to which a singular recorded event can be rendered as a playable score without erasing the features that give it its identity. For *Torrent*, notatability was a prior objective. The improvisation was undertaken with the explicit aim of later fixation and reperformance by another performer, and this commitment foregrounds the question of what a score can carry forward. Many fast jazz solos, for example, have entered notational and analytic circulation through transcription, but, often, transcriptions are unable to carry what defines the event, because the relevant musical information can reside in microtiming, timbral inflection, and the embodied feedback loop between performer and instrument. Much of this information is difficult to represent, or cannot be represented at all, within the constraints of standard Western staff notation. Transcriptions are often reductions, and repetition by another performer becomes a re-enactment guided by the score and other references rather than a reliable attempt to replicate the original act. In practice, performances emerge through an ecology of representations and references, including the score, one or more recordings, discussion with the composer, performers' knowledge of related repertoire and technique cultures, and the interpretive decisions made in rehearsals as well as in the moment of performance. Notation therefore acts as a selective translation. It stabilizes enough to make re-performance possible, while leaving non-notatable aspects to be reconstituted through the score in relation to recordings, composer feedback, and performers' situated know-how.

A significant challenge for notation arose from *Torrent*'s characteristics: fluctuating speed, absence of an underlying pulse, and inconsistent note groupings. In temporal terms, it unfolded in smooth time, a continuously varying, non-metric temporal field without a single stable reference pulse.[52] Traditional rhythmic notation, structured around proportional durations and metric regularity, cannot adequately convey the fluidity of a tempo that continually accelerates, decelerates, or pauses. One conceivable solution would be to segment the piece into discrete groups and notate each as a precise tuplet whose ratio corresponds to a momentarily stable speed. Yet tuplet notation presupposes a reference pulse, which would be arbitrary in this pulse-free improvisation. Establishing a pulse and then continuously tracking a succession of shifting tuplets would impose unintended accentuation patterns and substantial cognitive and physical burdens on performers, pulling against the more intuitive flow of the original event. Moreover, tuplets imply that speed remains constant within each notated group and then changes discretely at the next boundary, whereas in *Torrent* the tempo tends to evolve continuously rather than as a series of stepwise shifts.

Jarrett articulates similar concerns in his comments on the notation of *The Köln Concert*: "There are many places where notes are correct, but time is not, because on the recording I am playing completely out of metronomic time" (Jarrett, n.d.). His remark highlights how difficult it is to capture smooth time with a notational system whose basic premise is striation. Historically, this limitation was mitigated by the fact that notation was embedded in a shared practice of non-notated rubato, ornamentation, and, in earlier repertories, even instrumentation; performers were not expected to reproduce the written durations literally, but to supply stylistically consensual rhythmic nuance. The modern ideal that a musician should "play the rhythms as notated" is therefore comparatively recent and reflects a tightening of the link between score and sounding result. Western staff notation includes devices for indicating smooth-time processes, such as rubato, accelerandi or fermatas, but these markings remain approximate and sit uneasily with the idea of exact transcription. Jarrett's further observation that "it would almost need notation on every note to be accurate" (Jarrett, n.d.) effectively anticipates a scenario in which each event would require its own specialized temporal indication, something akin to a tuplet or tempo change on every note.

[52] Smooth time is explored further in Chapter 2.

These challenges underline that Western staff notation is both an affordance and a constraint: it can render certain temporal relations legible and repeatable, yet its built-in selectivity becomes limiting when the music emerges from a continuously varying, pulse-free improvisation. In Schuiling's terms, notation operates less as a neutral mirror than as an interface that shapes musical interaction and conditions musicians' creative agency (Schuiling, 2019, pp. 430–431). Earlier notation cultures sometimes addressed comparable temporal openness, not by increasing rhythmic specification but by withholding it, as in the seventeenth-century French unmeasured harpsichord preludes, where rhythmic values are seldom notated and the player creates the rhythmic profile on the basis of harmonic and linear implications, guided by multiple layers of slurring (for example, in Louis Couperin's unmeasured preludes; see Odermatt, 2018). Improvised music likewise includes subtle rhythmic flexibilities that resist precise quantification within staff notation, which returns the practical question of what a score fixes and what it leaves to performers (Benadon, 2009).

This selectivity is not merely technical but epistemic. A score functions as a located and partial specification, not as an all-determining, neutral transfer of musical information. Further, drawing on Haraway's account of situated knowledge, what notation stabilizes is mediated by bodies, instruments, technologies, and historically conditioned idioms and technique cultures that shape what counts as playable, intelligible, and stylistically meaningful (Haraway, 1988). In this sense, *Torrent* depends on modern flute design, contemporary technique regimes, and particular listening histories, so it would not straightforwardly translate into a seventeenth-century musicking ecology. Notation therefore distributes agency rather than fully containing it. It under-specifies fine-grained timing and timbral-gestural nuance, and it relies on the performer's tacit and sociohistorical know-how to reconstruct plausible musical actions. Regarding *Torrent*, the recording can function as additional evidence for pacing, articulation, and inflection.

In light of these conditions, my notational solution was to employ a continuous flow of sixteenth notes that accurately reflects pitches and phrase lengths, occasionally augmented by brief tuplets and thirty-second notes to indicate local accelerations without implying fixed proportional relationships. Notes were grouped either according to my original improvisational conceptions or consistently in groups of four to facilitate easier chunking and to support rapid execution. No explicit tempo indication was provided; instead, the only instruction specified: "In general, *Torrent* should be played very fast; however, it can also be quite rubato."

Here, "fast" is an open term. What counts as very fast for one performer is not necessarily very fast for another, because perceived and achievable speed depends on technique, instrument response, and the performance situation. Because the score includes no metronome marking, it can, in principle, accommodate, for example, a realization of ten minutes or more, if the note rate is less than half that of the source recording. In such cases, the injunction to play very fast is carried less by the score itself than by the surrounding reference network, including the source recording, feedback from the composer, shared technique cultures, and the interpretive decisions that emerge through rehearsal.

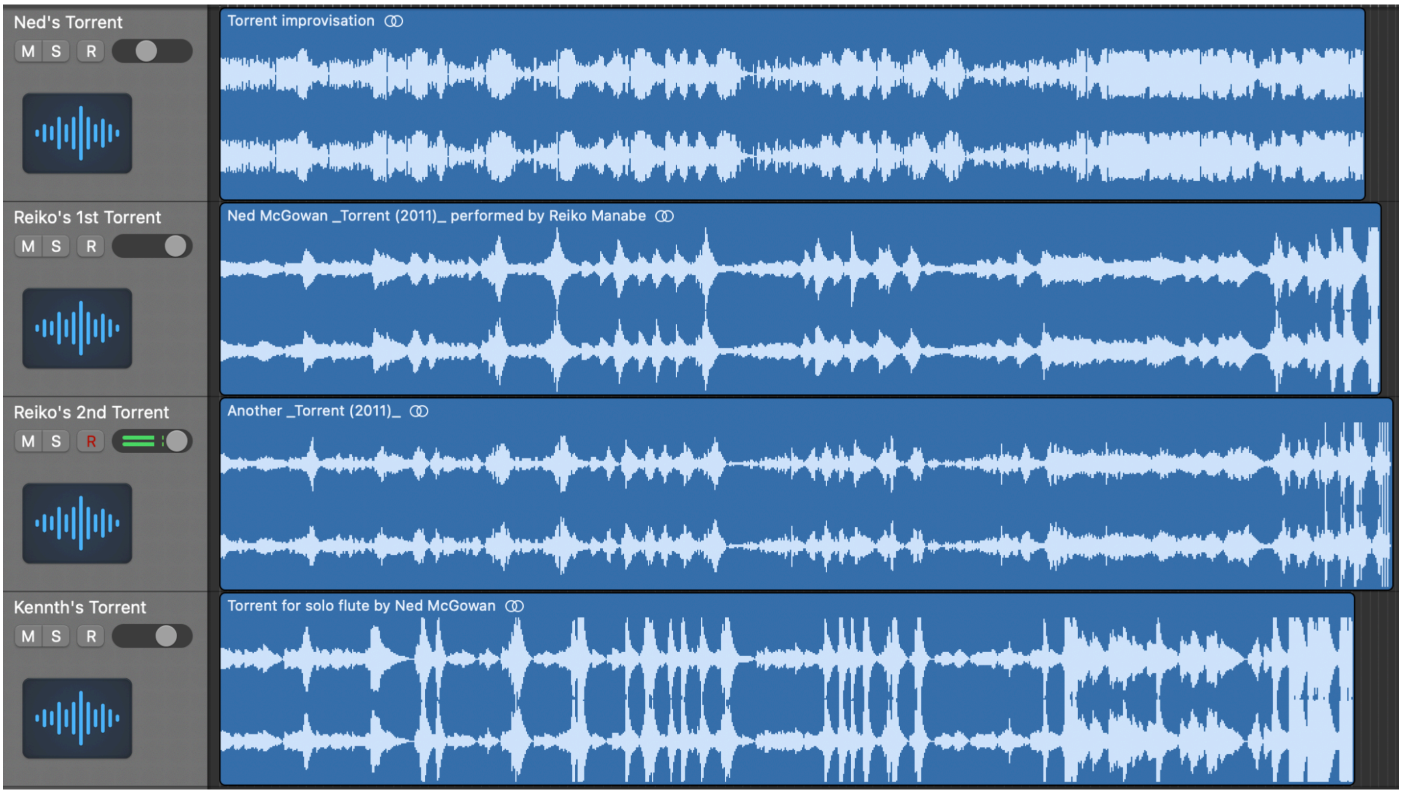
While inevitably introducing artificial rhythmic regularity, this notation allows substantial interpretive flexibility, deliberately avoiding precise quantification of tempo fluctuations. The *Torrent* score can be understood as an interface that entwines improvisation and notation rather than placing them in opposition. It gives performers something to perform while leaving temporal relations to be realized in performance, stabilizing the improvisation for re-performance without fully determining how it unfolds (Schuiling, 2019, p. 431; Schuiling, 2022, pp. 323–324). In this context, "rubato" admits two complementary readings. First, it legitimizes variations in local speed that arise from technical and cognitive limits, since certain passages can be executed faster than others. Second, it invites musical interpretation with respect to speed. Rather than drawing on a preexisting vocabulary of stylistic rubato, performers can respond to the emergent character of the notated line itself. Contour, register, articulation, breath and fatigue, perceived goal notes, and local climaxes can all become cues for stretching or compressing time. In a piece like *Torrent*, which does not inhabit a historically codified melodic harmonic idiom, such rubato arises from performers' embodied negotiation of the written line rather than from shared conventions about phrase rhythm.

To examine re-articulation of the *Torrent* score, I compare the speeds of four performances across the micro, meso, and macro framework of timescales. The first is my source improvisation, and the others are two different versions by Reiko Manabe and one by Kenneth Cox.

Example 5.7. *Torrent*, performed by Reiko Manabe, video.
Example 5.8. Another "Torrent," performed by Reiko Manabe, video.
Example 5.9. *Torrent*, performed by Kenneth Cox, video.

Before turning to measured timing comparisons, it is important to note that the reference conditions for these re-performances were not identical. Manabe and Cox had access to the source recording in addition to the score, although the extent to which they studied the recording is not known to me. A further variable is communicative proximity: unlike many historical situations in which notation had to travel without the composer, both players could in principle consult me directly about fingering, pacing, or sound ideals, a possibility that echoes earlier practice based on co-presence, apprenticeship, and oral transmission. Where the score functions as a reduced interface that stabilizes pitch and contour while leaving substantial temporal and timbral information implicit, the recording supplied additional cues about pacing, articulation, inflection, and local rubato. This difference matters for questions of repeatability: a score-only re-articulation would necessarily amplify interpretive reconstruction from sparse information, whereas a score-plus-recording can operate as a closer form of re-enactment grounded in the recorded reference. With those conditions in view, I now turn to timing comparisons across multiple temporal scales.

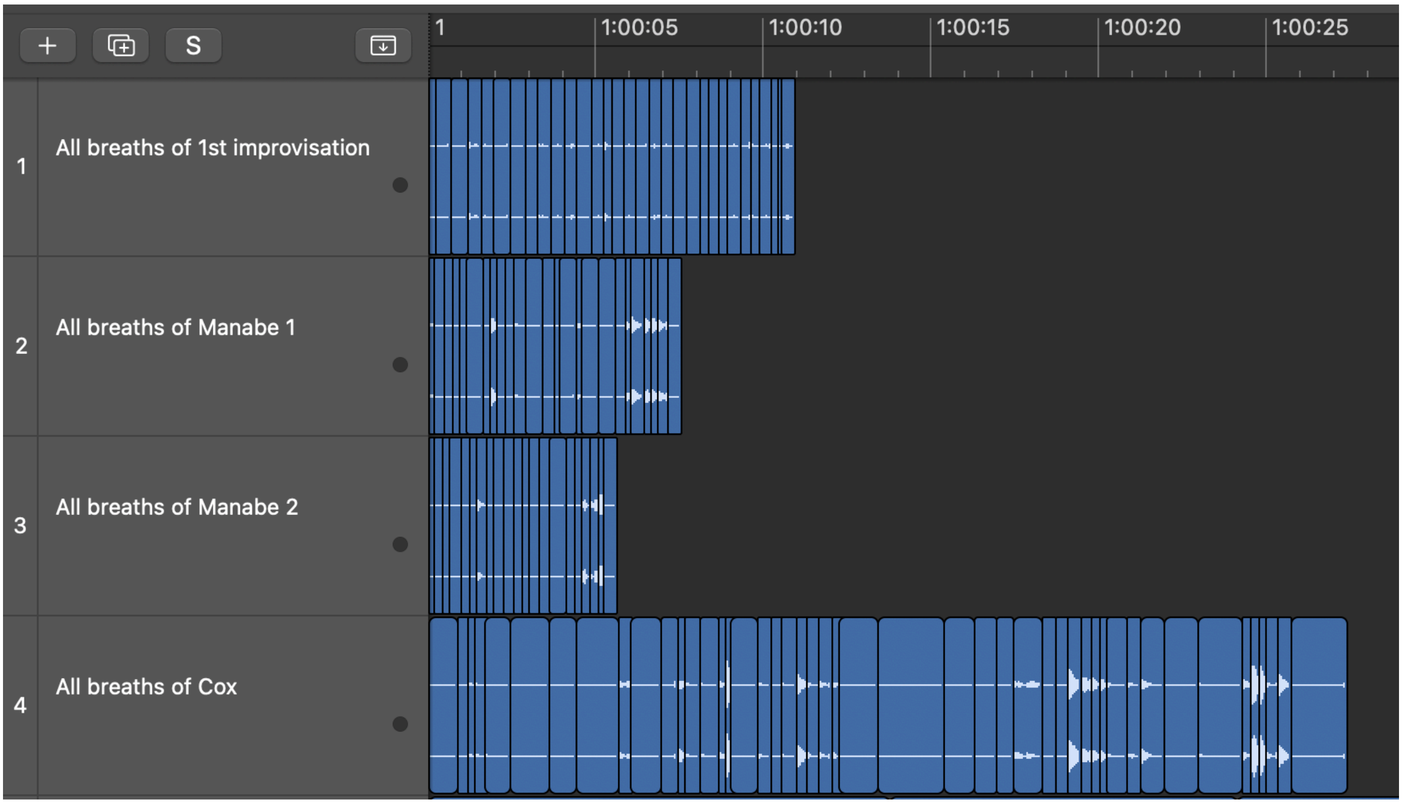
At the macro level, the total durations of the three new versions remain close to the source recording. Manabe's first version lasts 4 minutes 25 seconds, which is 1.2% longer than my source recording at 4 minutes 22 seconds. Her second version lasts 4 minutes 28 seconds (2.3% longer). Cox's version lasts 4 minutes 19 seconds (1.2% shorter).



Example 5.10. *Torrent*. Waveforms of all four performances, showing relative total durations

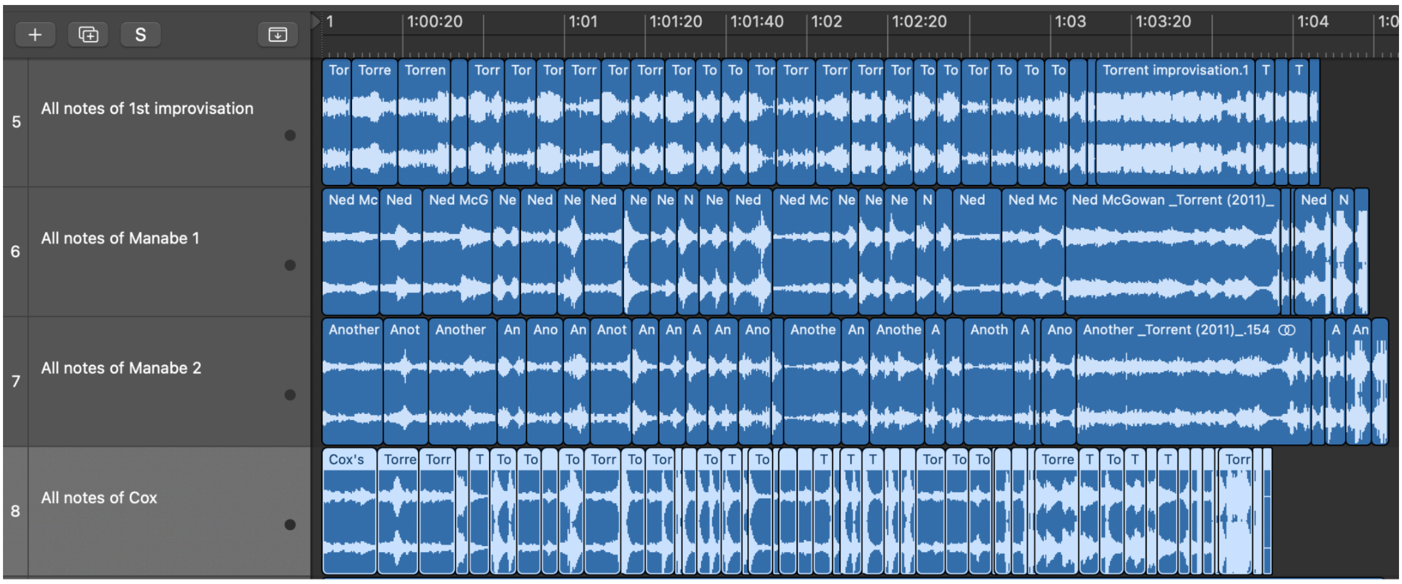
Total duration, however, conflates sounding time with pauses for breathing. In the source recording, I take 32 separate breaths, plus one extended passage of circular breathing from 3 minutes 21 seconds to 4 minutes 00 seconds. Manabe takes fewer discrete breaths, approximately 27 in both versions, and she relies on circular breathing more frequently than I did. Cox, by contrast, takes 47 breaths. He inserts many additional intakes beyond those notated and does not use circular breathing. These differences show how breath strategy redistributes speed over time, so that two performances can share similar overall durations while differing markedly in how speed is deployed. They also underscore that breath marks, like the rubato instruction discussed above, indicate a performative intention without fully determining its realization. Even when the score specifies breath locations, respiratory economy, projection demands, technique strategies, and interpretive choice reshape where and how breathing becomes necessary, re-situating the score within each performer's embodied conditions and performance situation.

If the breath pauses are removed and their durations are totaled, the four versions differ in their effective playing time. In the source recording, my 32 breaths total approximately 11 seconds. Manabe's breaths total approximately 7 seconds in her first version and 5 seconds in her second. Cox's breaths total approximately 27 seconds.



Example 5.11. *Torrent*. Waveforms of all breath pauses of all four performances

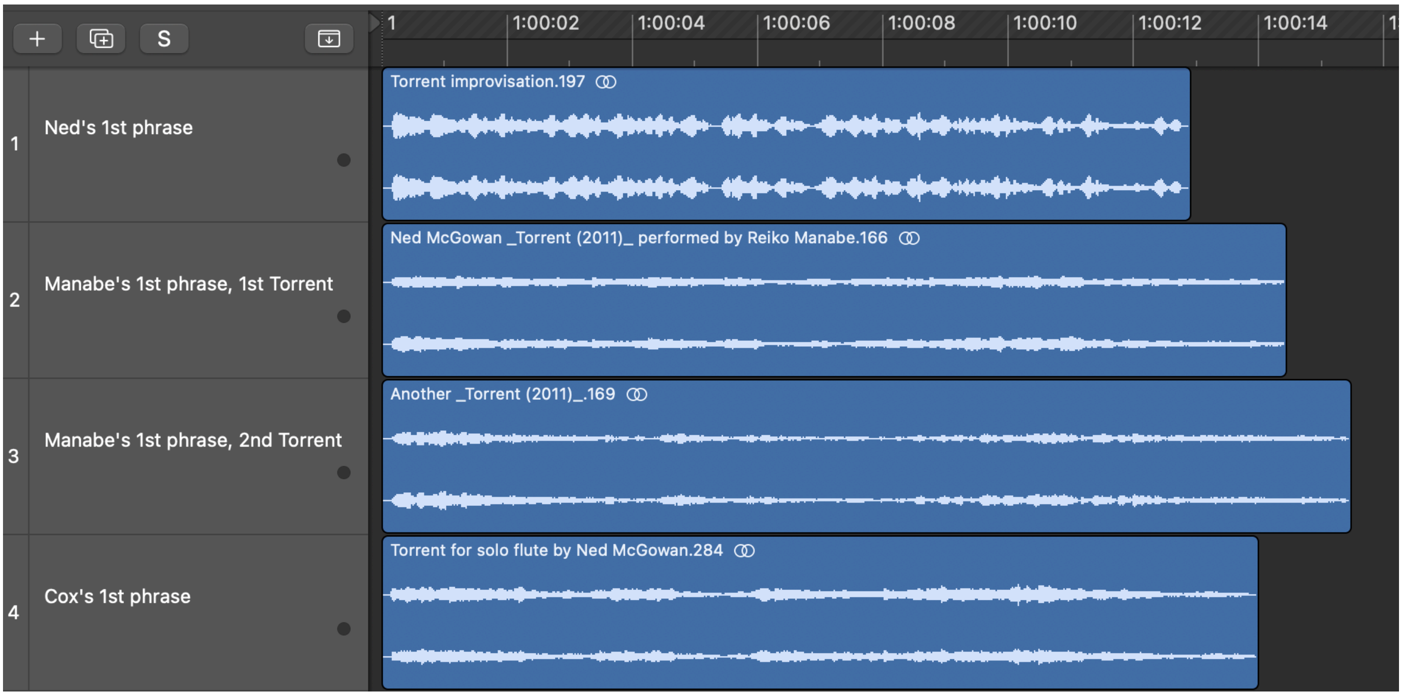
Subtracting breath time from total duration yields the following playing times. My playing time is 4 minutes 11 seconds. Manabe's playing times are 4 minutes 18 seconds (2.8% longer), and 4 minutes 23 seconds (4.8% longer). Cox's playing time is 3 minutes 52 seconds, which is 7.6% shorter than mine, a difference that is readily apparent in many phrases of his performance.



Example 5.12. *Torrent*. Waveforms of only played notes of all four performances, breaths cut out

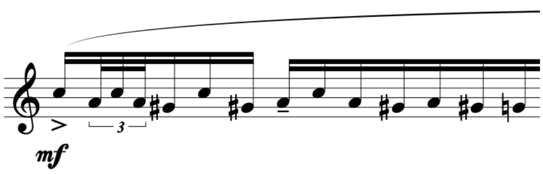
The contrast becomes clearer when speed is framed as temporal density, that is, the approximate number of notes divided by playing time. Taking the number of notes in the score, approximately 2,107, and dividing by the playing time yields average densities at the macro level. Cox's realization reaches about 9.1 notes per second. My realization reaches about 8.4. Manabe's realizations reach about 8.2 and 8.0. These averages remain coarse. They do not capture the microtiming of individual notes or groups of notes, the speed differences of individual phrases, nor do they convey how breathing produces either continuity or segmentation. They do, however, support a qualitative difference in pacing strategy. Manabe's reduced breathing and frequent circular breathing produce longer uninterrupted spans and a more continuous *moto-perpetuo* profile, even at a slower average note rate. Cox's higher note rate is paired with more frequent and often longer breath pauses, which can make the piece feel more "episodic" in some areas, with faster bursts separated by breaks.

This macro-level picture says little about how speed is distributed within the piece, and phrase-scale timings already reveal substantial divergence. Even within the first phrase, durations diverge substantially: 12.8 seconds in the source recording; 14.6 seconds in Manabe's first version (14.1% longer); 15.5 seconds in her second (21.1% longer); and 14.0 seconds in Cox's version (9.4% longer).



Example 5.13. *Torrent*. Waveform lengths of the first phrase of all four performances

At the micro level, interpretive differences appear immediately, beginning with the length of the first note. In the source recording I play the opening C briefly, as the initiation of a burst. Both Manabe and Cox hold it longer, giving it a more melodic character before moving into the figuration. Similar micro-differences recur throughout the piece, and they show how *Torrent* is not only reproduced but actively reconstituted through a performer's shaping of onset, duration, accent, and breathing.



Example 5.14. *Torrent*. Bar 1, score excerpt. Audio excerpt of the four different versions of the first note (McGowan, Manabe 1, Manabe 2, Cox).

Manabe and Cox as co-composers

These timing differences should not be understood as deviations from a fixed original. They show how re-performance can function as a form of co-composing, in which the performer reworks the piece in time. Following Barthes (1977), the score can be approached less as an authority that contains a single enactment and more as a script that is realized through acts of reading. Here, reading is inseparable from embouchure, breath economy, fingerings, and risk management. Manabe's two versions exemplify this co-composing role through continuity, oriented pacing decisions, and micro-level articulation choices, including the longer opening note. Cox's version exemplifies the same agency through a contrasting redistribution of pacing and breathing over time, yielding a different balance between uninterrupted spans and pauses for breathing, and therefore a different sense of drive across the line.

From the composer's perspective, such re-articulations feed back into compositional knowledge by clarifying how speed is not a single tempo value but an emergent outcome of how continuity, segmentation, and decision pressure are organized in performance. In that sense, Manabe and Cox do not simply perform *Torrent*. They each offer a recomposition of its temporal design within the affordances of the score and the reference ecology that surrounds it, and their versions make evident different solutions to the problem of sustaining speed under temporal pressure.

To connect these performance comparisons to questions of tactility and decision making under extreme speed, I now zoom in on two brief excerpts. Bar 13 is built from irregular pitch sets and illustrates how fluency can depend on fingering pathways and instrument-specific feel. In the source recording, this passage lasts 2.04 seconds. In Manabe's first version it lasts 2.20 seconds (7.8% longer). In her second version it lasts 2.16 seconds (5.9% longer). In Cox's version it lasts 2.17 seconds (6.4% longer). These modest but consistent differences invite a closer look at how embodied familiarity with the material can support immediate fluency for one performer while requiring reconstruction and rerouting for another.

Example 5.15. *Torrent*, bar 13, score excerpt. Audio (McGowan, Manabe 1, Manabe 2, Cox).

When I reread passages such as this, built from irregular sets, I find them immediately playable and legible, and I can take them in at a glance. This suggests that aspects of my embodied technique and my habitual fingering pathways are tacitly encoded in the notation, affording me recognition and fluency that may not generalize to other performers. In that sense, *Torrent* was calibrated to my own bodily playing habits, and re-performance is mediated by each performer's learned technique and by the specific instrument through which the score is realized. Even within the broadly standardized mechanics of the Boehm flute, variations in key placement, spring tension, tuning tendencies, and headjoint response alter tactile feel and the resistance profile of the air column, so actions that feel natural and economically viable to me can register as awkward or unstable for others. By contrast, passages in which I briefly hesitated while choosing subsequent notes, particularly longer scalar runs, can be performed more quickly by a performer who has internalized those scale patterns through preparatory practice, underscoring how different sensorimotor repertoires produce different pacing outcomes within the same notated line. The following example illustrates how both Manabe and Cox perform the scale passage faster than I did.

Example 5.16. *Torrent*, bar 4, score excerpt. Audio (McGowan, Manabe 1, Manabe 2, Cox).

This comparison highlights how different preparation routes, whether improvising in real time in the sounding present or learning from notation through repetition, influence the distribution of speed within a performance. It also clarifies a central point about interpretive openness. Music critic and journalist Tom Service, discussing Ferneyhough's compositional approach and characteristically dense notation, observes that the more information you give performers to interpret, the more open-ended rather than fixed the work can become, since every expressive mark becomes something that is played and interpreted differently (Service, 2012, ¶ 6). Under particular performance cultures and pressures, however, the same density of prescription can tighten into a correctness regime, narrowing interpretive variance when performers treat notated detail as binding and when rehearsal or adjudication contexts reward compliance over exploration. Rather than seeing limitations, Barrett similarly identifies opportunities in notation: "Even the most precisely notated score does not squeeze spontaneity out of existence, instead channeling it in many complex and subtle ways" (Barrett, 2019, pp. 43–44).[53]

Torrent adopts an alternative strategy through a deliberate reduction of detailed notational information, providing only essential indications of pitch, breathing, dynamics, and to play rapidly and rubato. Despite employing relatively straightforward notation, *Torrent* fosters interpretive individuality by emphasizing rapid execution and tactile responsiveness rather than complex instruction sets. By refraining from rigid temporal prescriptions, the notation preserves and interpretive latitude and invites performers to explore

[53] Although "channeling" can be read neutrally as a redirection of spontaneity through constraints, it can also be interpreted more critically as a form of regulation that privileges certain kinds of spontaneity over others.

their own solutions to pacing within a bounded field. That field is delimited by the written pitch sequence and by the status accorded to the source recording, which can function either as a normative anchor for re-enactment or, under more liberal performance assumptions, as only one possible interpretation of the notated line.

From the perspective of a listener, the question is not only how a performer produces speed, but how speed is perceived as energy, continuity, and drive in the sounding result. An empirical study titled "The Improvisational State of Mind" (Dolan et al., 2018) offers a focused illustration of how different performance approaches shape the perception of tempo and expressiveness. I use it heuristically here to illuminate one perceptual point pertinent to *Torrent* and to Ferneyhough's *Carceri d'Invenzione* IIb (as recounted in the opening story of the Introduction). In this multidisciplinary study, performers played the same Schubert piece twice: once in a "strict" mode (a prepared interpretation that prioritized technical precision, detailed score accuracy and risk avoidance), and once in a "let-go" mode (an improvisatory approach that relaxed strict note-by-note adherence). Although the "let-go" performances were objectively slower, listeners perceived them as faster and more dynamically compelling, largely due to more cohesive phrasing, gestural continuity, and heightened expressive engagement rather than increased measured tempo alone. While the stylistic context differs from the music considered in this chapter, the study nonetheless While the stylistic context differs from the music considered in this chapter, the study nonetheless helps separate two levels that are easy to conflate: first, what performers do with a score as a resource for action, and second, what listeners perceive in the sounding result. An audience will often never see the score, but notational regimes still matter indirectly because they shape rehearsal attention, bodily organization, and the kinds of continuity or risk a performer is willing or able to sustain, which in turn conditions perceived speed and energy. In this light, the findings underscore that tempo perception is not reducible to measured rate alone, and that performer orientation to the written score can be audible even when it is not visible. For *Torrent*, this suggests that perceived speed may depend less on absolute note rate than on continuity, phrasing, and the performer's orientation toward risk, even when the underlying notational prompt is comparatively sparse.

Reflecting further on my own experience described in the Introduction performing Ferneyhough's *Carceri d'Invenzione* IIb, I did not aim to disregard the rhythmic notation or to emphasize other elements over it. This experience underscored the significant influence of situational factors such as nervousness and competition, which typically accelerate performance speeds and, in my case, seemingly simplified them. Schick's observations should thus be contextualized within these competitive circumstances, where jurors generally adhere strictly to the score. His remark - that a memorized performance of Ferneyhough risks unintentionally quantizing its multiple tempi and complex tuplets into a handful of simplified speeds - further underscores how situational pressures can compress rhythmic nuance. In this sense, his feedback resonates with the broader themes of this chapter: notation, embodiment, and context interact dynamically, and under conditions of pressure or speed, even highly detailed rhythmic structures can collapse into more regularized forms. The reverse can also occur: instead of quantizing into a few stable speeds, pressure can destabilize timing and produce uneven, fragmented, or exaggerated rubato, increasing local variability even when the notation is precise.

5.10 Conclusion

This chapter has treated speed as a lens for understanding how musical creation unfolds, building on Nettl's suggestion to think in terms of rapid and slow composition rather than a strict opposition between composition and improvisation (Nettl, 1974, p. 6). The speed of creation map developed in Section 5.4 reframes these practices by foregrounding how quickly decisions must be made and how much reflective latitude is available before commitments become effectively irreversible.

Within this frame, *Torrent* offers a concentrated case study of creation under extreme temporal pressure. The work originated in a single high speed improvisation whose outcome was fixed first as a recording and then re-mediated as a score for other performers to re-articulate. Across this chain of fixations, the analyses of tactile processes, chunking, and flow show how decision compression shifts a larger share of shaping work onto embodied competencies and learned schemata, while still leaving room for moment to moment steering within the sounding present, at a tempo that remained workable for me.

The notational discussion in Section 5.9 clarifies what changes when a smooth time performance is provisionally and to a certain extent stabilized in a striated notational system. The *Torrent* score fixes pitch and contour while keeping rhythmic specification relatively coarse, creating an interface that enables re-performance without translating continuously varying timing into a strict correctness regime of notated microtiming. This strategy keeps the recording and the score active within a wider performance network that also includes rehearsal negotiation, situational pressures, and, when available, feedback from the composer. It also highlights how each re-performance becomes a situated translation rather than a reproduction of an original.

Taken together, three points can be stated plainly. First, the prior constraint of later fixation and transfer reshapes what it means to improvise at maximal speed. Second, the recording functions as a first fixation and the score as a second fixation, each with distinct affordances and losses. Third, the speed of creation systematically redistributes musical decision making across embodiment, tooling, and revision affordance. In this sense, *Torrent* offers a concentrated lens on how musical ideas can be generated at speed, partially stabilized through recording and notation, and made available for re-performance, while still bearing traces of the temporal ecology that produced them.

Schön's vocabulary helps name the mechanism behind this temporal shift. In *Torrent*, the action present contracted to moments, and task setting meant deciding, in the moment, how to balance continuity of flow, avoidance of repetition, and attention across several timescales. Even within that compressed window, reflection did not disappear. It took the form of rapid reappreciations and brief moments to plan that were folded into the ongoing action, which is what Schön describes as reflection-in-action under tight situational boundaries (Schön, 1983, pp. 77, 324).

Seen through the speed of creation map, deadlines and no revision constraints are not external add-ons but devices that reallocate decision making. In deferred time composition, an approaching deadline can accelerate the transition from exploratory revision toward embodied certainty. In real time creation, that acceleration becomes total. Conviction emerges from intensified focus, reliance on tacit and historically conditioned know-how, and the necessity of generating viable next actions as physical limits approach. These pathways to conviction, whether iterative refinement or high speed concentration, are different temporal ecologies rather than a hierarchy.

Conclusion

In music, time is constituted for performers and listeners through patterns of sound and silence. The rate at which they unfold is their speed, influencing listeners' perception and emotional responses profoundly. Within European art music discourses from the late eighteenth to early twentieth centuries, pedagogical and critical sources often aligned faster tempos with vitality or agitation and slower tempos with gravity, devotion or solemnity, while genre, meter, affect, and performance situation (for example liturgical, theatrical, salon or concert hall settings), together with venue acoustics, social function, and local listening conventions, mediated these associations. However, speed in music is far richer and more nuanced than tempo alone suggests. Over the last century, performers and composers have radically expanded the ways in which musical temporality can be conceived, experimented with, and embodied. To a great extent, this expansion was enabled by technological innovations including disc and tape recording, digital instruments, and software environments, which made possible new modes of listening, analysis, and composition. In doing so, they broadened the expressive palette of speed itself, shaping how fast or slow music can feel, how motion is perceived, and how time is experienced, and they explored extremes at the edges of performability and perceptibility. For music played by instrumentalists from notation, the palette of tools for speed includes traditional devices such as tuplets, rhythmic grouping, metric modulation, and tempo change, as well as newer structural strategies, for example click track polytempo, algorithmically generated scores or orchestrated spectral density manipulation. Speed is tied to compositional choices, interpretive decisions, performative embodiment, and listener engagement, making it an expressive component of musical meaning and experience. Every musical piece inherently embodies an approach to speed, implicitly or explicitly communicating something about its pacing. This dissertation has demonstrated a practice-based conceptual framework for understanding musical speed, integrating rhythmic techniques, performative embodiment, theoretical reflection, and situated musical knowledge. I have argued that speed is actively experienced and interpreted, rather than passively implemented, thereby encouraging interdisciplinary dialogues across artistic, cognitive-scientific, and philosophical domains.

Despite its ubiquity and centrality, speed as a concept remains surprisingly underexplored in relation to musical content and expressive potential. Musicological research has largely limited its discussion of speed to investigating the somewhat quantifiable parameters of tempo or microtiming, neglecting the full set of parameters responsible for the unfolding of music, and also broader, integrated expressive implications. Scientific research has touched upon aspects of musical speed through studies on timing accuracy, rhythmic synchronization, and physiological responses, yet these insights rarely integrate into concrete practical frameworks. Cognitive science and neuroscience offer significant insights into rhythmic processing and timing deviations, but their translation into tools and implications that are directly usable by musicians, including composers, remains underdeveloped. By highlighting these oversights, I have taken a holistic approach to speed that emerges from compositional, performative, and listening interactions, alongside a methodological, systematic, and reflective practice in which I applied, tested, and evaluated rhythmic tools (for example tempo transformation, tuplet systems, density strategies, and polytempo coordination) as well as embodied engagement, embedded within a musical practice and body of work. By explicitly theorizing speed in and through music as an expressive dimension, this dissertation invites new considerations of how musical pacing influences formal development and musical communication understood as interactions among performer and instrument, instrument and acoustics, musician and musician, performer and audience, medium and technology (such as guitar and amplifier), and between a composition and music history. How speed functions in creative artistic practice, taking real-world situations into account, provides a working reality which balances a wide range of considerations that often challenge single rule prescriptions about tempo markings, meter and subdivision, ensemble synchronization, and literal score fidelity. My perspective, with extensive practical experience as a composer, performer, and educator, enabled an insider's research into how speed functions practically within musical contexts.

In concluding this dissertation, I return to the central research inquiry: *What is speed in music, and how can I explore it creatively and practically within my artistic practice?* Throughout the preceding chapters, this inquiry has unfolded along two intertwined threads. In the first one, I have examined speed through concrete musical and bodily phenomena – from the thresholds of speed (illustrated with extreme Beethoven tempo examples) to rhythmic structures, temporal resolution, density, tuplets, and polytempo. In the other I have framed musical time via the concepts of smooth and striated time, drawing on ideas of layered identities, nonlinear temporal experience, and individual perception. The following discussion synthesizes these threads, drawing together the explorations of tempo thresholds, temporal resolution limits, density and motion, the (deconstructed) smooth/striated dichotomy, the LEMI model (Listener, Environment, Musical Interaction, a triadic account of how listener, environment, and musical material jointly shape experience) and situational perception (fast improvisation). In doing so, it traces how artistic, scientific, music-theoretical, and philosophical insights on speed intersect and how they converge in musical practice.

From an analytical and performative perspective, my research reaffirmed that speed in music is far more than a metronomic marking – it engages the physical mechanics of performance, the architecture of rhythm, and the limits of human perception. Chapter 2's section, Thresholds of Speed, was based upon my creative reworking of Beethoven's *Ninth Symphony* at radically different speeds, exploring both gradual shifts and extremes. This experiment compressed and expanded the work from durations of hours to fractions of a second, showing how identity changes at different perceptual thresholds. The same material iterated at different speeds undergoes qualitative shifts: at certain thresholds details collapse into texture, and beyond fusion rates repetition even becomes pitch. Speed thus spans from discrete motion to continuum. Pushing tempo to this brink, as in the performance of the movement "Telescopic Ladder" from my composition *Tools*, can paradoxically produce a textural sound, suggesting that when such loss of precision is anticipated and shaped it can be taken up as a compositional and performative resource.

Investigations of rhythmic structures and density showed how the number of musical events per unit duration and their distribution in time shape our sense of momentum or motion in music. Composers employ tuplets to stretch or compress the beat, creating new densities that effectively generate nuanced intermediate speeds within a single pulse and introduce new qualities of motion to the music. Likewise, the exploration of polytempo demonstrated how multiple tempi can coexist to enrich the temporal fabric of a piece. By superimposing multiple speeds, composers can create a stratified time experience: each layer presents its own rhythmic identity, yet the ear can also perceive the combined result as an integrated whole. This is remarkable in relation to speed because perceived pace can become plural and dynamic, depending on whether attention tracks a single layer or the overall composite texture. In my compositions *Building Music*, *For Bob* and *Sydney Polypulse*, I experimented with such stratifications, creating textures that allow for individuality and cohesiveness within layered tempo environments.

Crucially, these structural and compositional discoveries are inseparable from the performing body. Especially in Chapter 5, in discussing the "speed of creation", I show that playing at extreme speeds couples two processes: selective conscious choice within very short windows, and automatic execution supported by trained motor programs and muscle memory. In fast improvisation, deliberation, embodied technique, and situational awareness operate together as the musician chooses a continuation, rapidly considers alternatives, and executes it near the limits of playability. Speed therefore relates to a shifting balance between preparation and in-the-moment decision making, a balance that characterizes all musicking, but that becomes especially constrained and consequential at extreme rates of action. For instance, in *Torrent* I confronted this directly by creating passages so rapid and dense that performing them became an exercise in balancing tension and relaxation, finding efficient movement strategies to maintain accuracy. These concerns extend from the moment of creation to the later performability of the resulting materials. In *Building Music* the articulation limits of repeated notes tested endurance and precision, and in polytempo pieces performers confronted the body's natural tendency to synchronize with nearby musicians, requiring heightened attentional control. The compositional lens of this research therefore provided concrete strategies to harness speed, while also charting the outer limits of the playable and the perceivable.

Parallel to the compositional and musical analysis, I employed a philosophical framework to make sense of musical speed, chiefly through the concepts of smooth and striated time. Borrowed and adapted from Boulez's terminology, these concepts offered a vocabulary for understanding different modes of temporality in music. In striated time, musical events are organized along a grid of countable, discrete units. Rhythmical grids such as pulse and tuplets, whether implicitly conceived by the performer or explicitly expressed in the music, produce a high degree of regularity, and only such striations can give measurable accounts of speed because of their regularity. By contrast, smooth time is a temporal space that unfolds without the guidance of a strict pulse or predictable measure, experienced in musical moments where time feels suspended or fluid, for example in an unmeasured cadenza, a sustained drone, or improvisatory passages that follow gesture rather than a fixed tempo reference. Striation enables character in several ways. The superimposition of grids, through the use of tuplets, creates structures with different speeds and different numerical properties, enabling variety in phrasing. At the same time, however, rhythms articulated with a grid can create irregularity that destabilizes striation, and also microtiming in human performance produces expressive deviations from it. This interplay suggests that smooth and striated time are not strict opposites but endpoints on a continuum, with most musical experiences blending elements of both. Striation clarifies musical structure, enabling salient qualities such as pulse, systematic phrasing, and coordination between musicians, while smooth time emerges from expressive elements such as microtiming and irregular rhythms. By framing speed in terms of this alleged and deconstructed dichotomy, it can be understood through a lens that illuminates its significance for both listeners and creators.

The idea of layered identities in musical time emerged from combining the smooth/striated framework with the polytempo and density techniques described earlier. While traditionally layers in music have their own identity of speed (think, for example, bass and melodic lines), this conceptualization leads to avenues of new creations. Each independent tempo layer in a polytemporal piece may possess its own striated temporal character, yet the coexistence of multiple layers creates a higher-level smoothness – an unpredictable, nonlinear superposition of speeds. This creates a situation where the perspective of the listener emerges as important in the experience of speed. Listeners might latch onto one layer or another at a time, effectively shifting their perspective among multiple temporal identities. This relates to the notion of nonlinear time: music need not unfold as a single, linear narrative that everyone experiences identically. Instead, as I argued in the section on LEMI and situational perception, time in music is multi-dimensional and personal. Different individuals may experience the form and speed of a piece differently, depending on where they focus their attention and how they internally measure the passing of time. These coexisting interpretations underscore a key philosophical insight: musical time is not monolithic. It is experienced through a lattice of situated layers even as more objective structures underlie the surface. Moreover, listening is not purely forward moving. Recognition of a returning theme, harmony, or motive recruits memory and can produce a partial reexperience of earlier moments, which can compress or dilate the felt pace and further undermines any strictly linear account of musical time.

The role of the listener's and performer's situated temporal experiences has been a through-line in this discussion, reinforcing a concept often highlighted in phenomenological and poststructural thought. Drawing on the LEMI model introduced in Chapter 2, I accounted for how contextual and personal factors shape the perception of musical time. The LEMI framework catalogues the "multitude of factors which impact on [the] sense of time during music listening," from the listening environment to the listener's mood, age, familiarity with the music, and even the performer's approach, and emphasizes that these elements are dynamic and can shift during the listening experience (Phillips, 2022, p. 11). Donna Haraway's concept of *situated knowledge* resonates strongly here. Translating her insights to musical terms, any judgment of musical speed arises from a particular situated standpoint – that of a given listener or performer in a given moment and place. Embracing this idea enriches the approach to speed: it urges consideration of whose sense of time is being referenced, and how differing circumstances might yield different experiences of the same tempo or density. Moreover, it aligns with Christopher Hasty's theoretical stance that meter and rhythm are *emergent* in real time, not fixed absolutes. Hasty posits that meter is a *constitutive process* wherein each event's duration is shaped by the next, emphasizing process over product and qualitative change over quantitative measurement (Hasty, 1997, p. x). This view reinforces my philosophical throughline: musical time (and thus speed) is something we actively create and perceive in the moment.

One of the most important outcomes of this research is the realization of how these technical and philosophical perspectives on speed converge in artistic practice. Far from being contradictory, they inform and enhance each other. The music-theoretical analyses provided the tools and parameters, while the philosophical inquiry provided the aesthetic and conceptual grounding. In composing and performing new works like *Torrent* and *Sydney Polypulse*, I found that the practical decisions were often guided by conceptual aims. For example, in *Torrent* I wasn't exploring extreme speed merely to showcase virtuosity; rather, I was investigating what musical intensity emerges when notes saturate the ear's attention. The result was a composition that deliberately rides the line between order and disorder – a flurry of figures executed so rapidly that they coalesce into a kind of smooth textural wash, perhaps similar to jazz critic Ira Gitler's description of saxophonist John Coltrane's improvisations on his album *Soultrane* as "sheets of sound" (Gitler, 1958).

Conversely, in *Sydney Polypulse*, my use of multiple simultaneous tempos was a practical outgrowth of wanting to represent *layered time* in music – an idea directly inspired by the philosophical discussions of nonlinear, individualized time and the uncoordinated sounds in everyday life. Each instrument operates in its own tempo "orbit," creating a musical scenario where time is relative depending on which layer one attends to. Implementing required technological solutions such as haptic metronomes and spatial separation for performers to maintain independent tempos, proving that conceptual goals can drive musical innovation. A particularly clear example is my etude *The Speed of Time*, which embodies many of the dissertation's core themes in a single work.

Example 6.1. *The Speed of Time*, video.

Each bar lasts precisely six seconds, articulated by an audible metronome click that externalizes clock time. Against this fixed reference, the musical surface moves from isolated attacks to progressively denser subdivisions, so that what begins as an almost schematic striated tuplet gradually fills the span with increasingly continuous activity. The metronome therefore sets machine precision against the performer's microtiming and bodily variability, making audible how human timing both aligns with and departs from an external grid as density increases. The work thus bridges technical and philosophical perspectives by showing how density, tuplet structure, smooth and striated time, and the relation between clock time and lived duration intersect in a single artistic practice, while also raising questions about the limits of performance and the role of technology in amplifying human characteristics.

As shown in *The Speed of Time*, the convergence of technical and philosophical threads reframed my approach to compositional and performative strategies. Instead of viewing speed as an isolated parameter, I now approach it as a portal to reimagining musical structure and experience. A composition can be structured around gradual changes in density, starting from a sparse texture and accelerating into a flurry, not just to increase excitement, but to explore how the very *perception* of time morphs along that trajectory. An improviser might deliberately shape a rubato passage to evoke smooth time before locking back into a striated, metered groove, sculpting the listener's temporal experience between a feeling of timelessness and the structure of clock-time. It is a shift from thinking of pace as a static setting to understanding speed as form-bearing. Just as harmony or timbre can define a piece's identity, so can the deployment of speed and temporal interplay.

The theoretical grounding from scholars like Hasty, Clarke, and Haraway, alongside empirical models like LEMI, fortifies these practical insights. Hasty's processual view of rhythm validates the creative intuition that time can be stretched, contracted, and formed by musical events themselves. Clarke's ecological and embodied perspective emphasizes that the experience of musical time is an active engagement. Listeners and performers enter a temporal relationship with the music, aligning their bodies and attention with its rhythms and flows (Clarke, 2005, p.71). This encourages performers to be conscious of how their own sense of time can influence the audience's, and conversely how a listener's background might influence what they hear in a piece (Phillips, 2022). Haraway's philosophy (1988), urging acknowledgment of partial perspectives, adds an ethical and epistemological dimension: it suggests that as artists we should embrace the diversity of temporal experiences rather than attempting to impose a single "correct" one. In practical terms, this might mean designing works that allow flexibility or creating listening situations that invite introspection on time.

Ultimately, by integrating the technical mastery of speed with a philosophical understanding of time, this dissertation offers a comprehensive answer to the first half of the research question: what is speed in music? It is not just a bpm number or a virtuosic feat; it is a multifaceted phenomenon encompassing physical limits, cognitive perception, and conceptual meaning. Speed can be metric and mechanical, but it can also be fluid and experiential. It lives in the tension between the quantifiable and the ineffable – between the tick of the metronome and the felt duration of a moment, a polarity that resonates with Bergson's distinction between clock time and lived *durée*. Building on this, my earlier discussions of Bergson, Hulse, Boulez, Grisey and Vriezen help to show how smooth and striated models reveal both the possibilities and limitations of temporal description. For instance, Bergson's notion of indivisible duration highlights why moments of musical smoothness resist reduction to metric divisions, while Hulse insists that striation, although real, only emerges within smooth flow. Vriezen's perspective on multiple modalities of musical time and Grisey's expanded typology further deconstruct the binary opposition, suggesting multiple overlapping logics of musical time, from periodic predictability to stochastic distributions. These reflections reinforce that speed cannot be isolated from broader temporal debates: tuplets, polytempo, and density shifts gain significance not only as compositional means but as nodes within a multidimensional network of temporal experience. Thus I have demonstrated how musical tools and philosophical perspectives converge in practice, situating speed within the evolving conversation about the nature of musical time. How can musicians utilize it creatively and practically? By applying the technical findings – expanding rhythmic vocabularies, using tuplets and polytempi, minding bodily ergonomics – in tandem with the philosophical insights – playing with smooth/striated contrasts, addressing the listener's perception, and attending to singular performance situations, venue acoustics, social functions, and listening conventions –

they can craft musical works that harness speed as a core expressive resource. The act of composition or performance becomes, in a sense, an experiment in temporal physics: composing with speed is composing with the fabric of time itself. By reframing compositional and performative strategies around this idea, musicians aim to create music that not only pushes tempos for excitement, but more fundamentally, shapes how time is experienced during the artistic encounter.

The dissertation has integrated theory, analysis, artistic intention, experimentation, scientific literature, best practices, and reflective interventions, yet is still limited in several ways. The artistic research method privileges personal practice, and while this yields depth, it cannot and does not claim universality. In Haraway's terms, this situatedness is not a deficit but an integral aspect of all research. The examples are mostly rooted in my own compositional and performative work, which cannot generalize to all musical contexts. Due to its ubiquity in all music, there is much more to learn about the applications of tools and expressions of speed in the work of other artists. The reliance on Western art music contexts, though enriched with cross-cultural references, leaves scope for broader ethnomusicological comparison. Empirical studies cited are interpreted through artistic framing, not experimental replication. These limits, however, are also strengths, allowing the research to remain grounded in lived practice, explicating individual choices while engaging with broader discourses.

This research may have significant implications, embedded within a musical practice and body of work. It offers practical and theoretical insights across different domains: for composers, it provides tools for structuring speed beyond tempo using density, tuplets, polytempo, and perceptual thresholds; for performers, it suggests strategies for navigating high-speed improvisation, ensemble coordination in polytempo, and expressive timing; for teachers and students, it enriches rhythmic pedagogy, helping learners perceive and produce speed in nuanced ways; for scholars, it reframes speed as a central theoretical category connecting artistic practice to cognitive science and philosophy; and for technology developers, it indicates applications for haptic metronomes and spatialized performance setups.

In order to triangulate what speed in music is, this dissertation took a portfolio approach, assembling a number of investigations which are by no means exhaustive, but which demonstrated essential building blocks and practical demonstrations in sound, visuals, and scores. While the structural nuts and bolts of tuplets and their relation to pulse are clear, further study into subtle perceptual thresholds at the extremes could be illuminating. Comparative studies could also be interesting, testing differences among groups such as musicians versus non-musicians, younger versus older listeners, or European versus non-Western audiences.

Future work could expand in several directions: ethnomusicological inquiry could examine how speed is conceptualized in diverse musical traditions, empirical research could test perceptual hypotheses such as the role of density in motion or the cognitive effects of layered polytempi, and artistic collaborations could further explore polytempo, haptic technologies, and the various potentialities between speed and improvisation. Musicological study could investigate approaches to speed among the different parameters of music - rhythm, meter, melody, harmony, timbre, dynamics, texture - while philosophical reflection could continue probing how speed in music illuminates the nature of time itself. Creative artistic explorations are also possible with many of the findings of this dissertation, such as with pieces that reveal survival-based technical specifications, compositions that explicitly influence temporal resolution and modulate the listener's speed of attention, works that reflect non-human perceptual speeds, pieces that explore changes in expression through subtle speed differences or ones that illuminate microtiming with the use of clock-time instruments. Most importantly, further research can continue to integrate artistic practice with theory and science, ensuring that speed is not relegated to a secondary parameter but recognized as an important dimension of musical life.

In conclusion, speed in music links measurable temporal structures to lived temporal experience, connecting tempo, subdivision, density, and microtiming to perceived motion, attention, and meaning. This concluding reflection has synthesized technical tools intrinsic to music (rhythm, meter, notation, articulation, and texture) and philosophical perspectives, showing that they converge on a common understanding: musical speed is relational. It arises from relationships – between musical events (technically), between bodily motions (physically), and between minds and contexts (philosophically). The inquiry has come full circle to affirm that, by understanding those relationships, practitioners can gain creative control over speed's role in artistic practice. Tempo and rapidity are no longer treated merely as challenges or effects; they can function as major structural elements that define form, create meaning, and transform experience. In this sense, the concept of speed, enriched by the lenses of technique and theory, reframes contemporary approaches to composition and performance and opens new horizons for the exploration of musical time.

References

Agawu, V. K. (1995). *African rhythm: A Northern Ewe perspective*. Cambridge University Press.

Ammirante, P., Patel, A. D., & Russo, F. A. (2016). Synchronizing to auditory and tactile metronomes: A test of the auditory–motor enhancement hypothesis. *Psychonomic Bulletin & Review, 23*, 1882–1890. https://doi.org/10.3758/s13423-016-1067-9

Andriessen, B. (1996). *Tetterettet: Interviews met Nederlandse improviserende musici*. Tandem Felix.

Andriessen, L. (2002). *Gestolen tijd: Alle verhalen* (M. Zegers, Ed.). Querido.

Arditti, I., & Platz, R. H. P. (2013). *The techniques of violin playing* [Book and DVD]. Bärenreiter.

Arom, S. (1991). *African polyphony and polyrhythm: Musical structure and methodology*. Cambridge University Press.

Bach, C. P. E. (1949). *Essay on the true art of playing keyboard instruments* [*Versuch über die wahre Art das Clavier zu spielen*] (W. J. Mitchell, Trans. & Ed.). W. W. Norton. (Original work published 1753–1762).

Bailey, D. (1992). *Improvisation: Its nature and practice in music*. British Library National Sound Archive.

Barlow, C. (1984). *Bus journey to Parametron (all about "çoğluotobüsişletmesi")* (2nd ed.). Feedback Studio. (Original work published 1980; Feedback Papers, Vols. 21–23)

Barlow, C. (2001). On the quantification of harmony and metre. In *The ratio book* (Feedback Papers 43, pp. 1–20). Feedback Studio.

Barrett, R. (2019). *Music of possibility*. Vision Edition.

Barthes, R. (1977). The death of the author. In *Image–music–text* (S. Heath, Trans.; pp. 142–148). Fontana.

Benadon, F. (2009). Gridless beats. *Perspectives of New Music, 47*(1), 135–164.

Berliner, P. F. (1994). *Thinking in jazz: The infinite art of improvisation*. University of Chicago Press.

Bernard, J. W. (1988). The evolution of Elliott Carter's rhythmic practice. *Perspectives of New Music, 26*(2), 164–203.

Besser, G., Duncan, C., & Quilliam, J. (1966). Modification of the auditory flutter fusion threshold by centrally acting drugs in man. *Nature, 211*(5049), 751. https://doi.org/10.1038/211751a0

Blauert, J. (1997). *Spatial hearing: The psychophysics of human sound localization* (Rev. ed.). MIT Press.

Blesser, B., & Salter, L.-R. (2007). *Spaces speak, are you listening? Experiencing aural architecture*. MIT Press.

Bolton, T. L. (1894). Rhythm. *The American Journal of Psychology, 6*(2), 145–238.

Borgdorff, H. (2012). *The conflict of the faculties: Perspectives on artistic research and academia*. Leiden University Press.

Boulez, P. (1975). Boulez on music today (S. Bradshaw & R. R. Bennett, Trans.). Faber and Faber. (Original work published 1963)

Boulez, P. (1986). *Orientations: Collected writings* (J.-J. Nattiez, Ed.; M. Cooper, Trans.). Harvard University Press.

Brøvig-Hanssen, R., Sandvik, B., Aareskjold-Drecker, J., & Danielsen, A. (2021). A grid in flux: Sound and timing in electronic dance music. *Music Theory Spectrum*, *44*(1), 1–16. https://doi.org/10.1093/mts/mtab013

Campbell, E. (2013). *Music after Deleuze*. Bloomsbury.

Chase, W. G., & Simon, H. A. (1973). Perception in chess. *Cognitive Psychology*, *4*(1), 55–81.

Chatterjee, A. (2013). *The aesthetic brain: How we evolved to desire beauty and enjoy art*. Oxford University Press.

Chion, M. (1994). *Audio-vision: Sound on screen* (C. Gorbman, Trans.). Columbia University Press. (Original work published 1990)

Chirico, A., Serino, S., Cipresso, P., Gaggioli, A., & Riva, G. (2015). When music "flows". State and trait in musical performance, composition and listening: A systematic review. *Frontiers in Psychology*, *6*, 906. https://doi.org/10.3389/fpsyg.2015.00906

Christensen, J., Slavik, L., Nicol, J. J., & Loehr, J. D. (2023). Alpha oscillations related to self–other integration and distinction during live orchestral performance: A naturalistic case study. *Psychology of Music*, *51*(1), 295–315. https://doi.org/10.1177/03057356221091313

Clarke, E. F. (1999). Rhythm and timing in music. In D. Deutsch (Ed.), *The psychology of music* (2nd ed., pp. 473–500). Academic Press.

Clarke, E. F. (2005). *Ways of listening: An ecological approach to the perception of musical meaning*. Oxford University Press.

Clayton, M., Sager, R., & Will, U. (2005). In time with the music: The concept of entrainment and its significance for ethnomusicology. *ESEM CounterPoint*, 1.

Cobussen, M. (2017). *The Field of Musical Improvisation*. Leiden University Press.

Coda Music Technology. (1988). *Finale* [Computer software]. Coda Music Technology. https://www.muzines.co.uk/articles/coda-music-finale/2300

Collins, N. (2010). *Introduction to computer music*. Wiley.

Cowell, H. (1928). New terms for new music. *Modern Music*, *5*(4), 21–27.

Cowell, H. (1996). *New musical resources* (D. Nicholls, Ed.). Cambridge University Press. (Original work published 1930 by Alfred A. Knopf)

Cox, A. (2011). Embodying music: Principles of the mimetic hypothesis. *Music Theory Online, 17*(2). https://mtosmt.org/issues/mto.11.17.2/mto.11.17.2.cox.php

Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience*. Harper & Row.

Dack, J. (2009). Stockhausen's *Kontakte* (1958–60): Analysis and context. *Contemporary Music Review, 28*(1), 5–22.

Dean, R. T., & Bailes, F. (2016). Cognitive processes in musical improvisation. In G. E. Lewis & B. Piekut (Eds.), *The Oxford handbook of critical improvisation studies* (Vol. 1, pp. 39–55). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780195370935.013.007

Deleuze, G. (1992). Ethology: Spinoza and us. In J. Crary & S. Kwinter (Eds.), *Zone 6: Incorporations* (pp. 625–633). Zone Books.

Deleuze, G., & Guattari, F. (1987). *A thousand plateaus: Capitalism and schizophrenia* (B. Massumi, Trans.). University of Minnesota Press. (Original work published 1980)

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience, 18*, 193–222. https://doi.org/10.1146/annurev.ne.18.030195.001205

Dietrich, A. (2004). Neurocognitive mechanisms underlying the experience of flow. *Consciousness and Cognition, 13*(4), 746–761.

Doffman, M., Payne, E., & Young, T. (Eds.). (2021). *The Oxford handbook of time in music*. Oxford University Press.

Dolan, D., Jensen, H. J., Mediano, P. A. M., Molina-Solana, M., Rajpal, H., Rosas, F., & Sloboda, J. A. (2018). The improvisational state of mind: A multidisciplinary study of an improvisatory approach to classical music repertoire performance. *Frontiers in Psychology, 9*, Article 1341. https://doi.org/10.3389/fpsyg.2018.01341

Eagleman, D. (2015). *The brain: The story of you*. Pantheon.

Eames, C., & Eames, R. (Directors). (1977). *Powers of ten* [Film]. IBM Corporation.

Epstein, D. (1995). *Shaping time: Music, the brain, and performance*. Schirmer Books.

Farrington, J. (2017, July 26). *"Rhapsody in Blue"—George Gershwin, piano; Paul Whiteman Orchestra (1924).* Library of Congress, National Recording Preservation Board. https://www.loc.gov/static/programs/national-recording-preservation-board/documents/RhapsodyInBlue.pdf

Fernández-Sotos, A., Fernández-Caballero, A., & Latorre, J. M. (2016). Influence of tempo and rhythmic unit in musical emotion regulation. *Frontiers in Computational Neuroscience, 10*, 80.

Fitch, W. T. (2006). The biology and evolution of music: A comparative perspective. *Cognition, 100*(1), 173–215. https://doi.org/10.1016/j.cognition.2005.11.009

Fritsches, K. A., Brill, R. W., & Warrant, E. J. (2005). Warm eyes provide superior vision in swordfishes. *Current Biology, 15*(1), 55–58. https://doi.org/10.1016/j.cub.2004.12.064

Gann, K. (1985). *The music of Conlon Nancarrow*. Cambridge University Press.

Godøy, R. I. (2018). Motor constraints shaping musical experience. *Music Theory Online, 24*(3). https://doi.org/10.30535/mto.24.3.8

Godøy, R. I., & Leman, M. (Eds.). (2010). *Musical gestures: Sound, movement, and meaning*. Routledge.

Goebl, W., & Palmer, C. (2009). Synchronization of timing and motion among performing musicians. *Music Perception*, 26(5), 427–438. https://doi.org/10.1525/mp.2009.26.5.427

Grahn, J. A. (2012). See what I hear? Beat perception in auditory and visual rhythms. *Experimental Brain Research, 220*(1), 51–61. https://doi.org/10.1007/s00221-012-3114-8

Grahn, J. A., & McAuley, J. D. (2009). Neural bases of individual differences in beat perception. *NeuroImage, 47*(4), 1894–1903. https://doi.org/10.1016/j.neuroimage.2009.04.039

Greshak, J. (2007a). Tempo scales in polytempo music. *Polytempo*.

Greshak, J. (2007b). The word "polytempo." *Polytempo*.

Grisey, G. (1987). Tempus ex machina: A composer's reflections on musical time. *Contemporary Music Review, 2*(1), 239–275.

Grondin, S. (2010). Timing and time perception: A review of recent behavioral and neuroscience findings and theoretical directions. *Attention, Perception, & Psychophysics, 72*(3), 561–582. https://doi.org/10.3758/APP.72.3.561

Grupe, G. (2005). Notating African music: Issues and concepts. *The World of Music, 47*(2), 87–103.

Haraway, D. (1988). Situated knowledges: The science question in feminism and the privilege of partial perspective. *Feminist Studies, 14*(3), 575–599. https://doi.org/10.2307/3178066

Harley, J. (2004). *Xenakis: His life in music*. Routledge.

Hartenberger, R. (2016). *Performance practice in the music of Steve Reich*. Cambridge University Press.

Hasty, C. (1997). *Meter as rhythm*. Oxford University Press.

Hook, J. (2011). How to perform impossible rhythms. *Music Theory Online, 17*(4). https://doi.org/10.30535/mto.17.4.1

Hove, M. J., Marie, C., Bruce, I. C., & Trainor, L. J. (2014). Superior time perception for lower musical pitch explains why bass-ranged instruments lay down musical rhythms. *Proceedings of the National Academy of Sciences, 111*(28), 10383–10388. https://doi.org/10.1073/pnas.1402039111

Huggett, N. (2024). Zeno's paradoxes. In E. N. Zalta & U. Nodelman (Eds.), *The Stanford Encyclopedia of Philosophy*(Fall 2024 ed.). Metaphysics Research Lab, Stanford University. https://plato.stanford.edu/archives/fall2024/entries/paradox-zeno/

Huron, D. (2006). *Sweet anticipation: Music and the psychology of expectation*. MIT Press.

Inger, R., Bennie, J., Davies, T. W., & Gaston, K. J. (2014). Potential biological and ecological effects of flickering artificial light. *PLOS ONE*, *9*(5), e98631. https://doi.org/10.1371/journal.pone.0098631

Iyer, V. (2002). Embodied mind, situated cognition, and expressive microtiming in African-American music. *Music Perception*, *19*(3), 387–414.

Jones, M. R. (2019). *Time will tell: A theory of dynamic attending*. Oxford University Press.

Kozak, M. (2020). *Enacting musical time: The bodily experience of new music*. Oxford University Press.

Kramer, J. D. (1988). *The time of music*. Schirmer Books.

Keller, P. E. (2007). Musical ensemble synchronisation. *Proceedings of the International Conference on Music Communication Science*, 5–7 December, Sydney, Australia.

Keller, P. E., & Repp, B. H. (2005). Staying offbeat: Sensorimotor syncopation with structured and unstructured auditory sequences. *Experimental Brain Research*, 163(3), 310–326.

Kraus, N., & Chandrasekaran, B. (2010). Music training for the development of auditory skills. *Nature Reviews Neuroscience*, *11*(8), 599–605. https://doi.org/10.1038/nrn2882

Land, M. F., & Nilsson, D.-E. (2012). *Animal eyes* (2nd ed.). Oxford University Press.

Large, E. W. (2008). Resonating to musical rhythm: Theory and experiment. In S. Grondin (Ed.), *The psychology of time*(pp. 189–232). Emerald.

Large, E. W., & Jones, M. R. (1999). The dynamics of attending: How people track time-varying events. *Psychological Review, 106*(1), 119–159. https://doi.org/10.1037/0033-295X.106.1.119

Large, E. W., & Kolen, J. F. (1994). Resonance and the perception of musical meter. *Connection Science, 6*, 177–208.

Large, E. W., & Palmer, C. (2002). Perceiving temporal regularity in music. *Cognitive Science, 26*, 1–37.

Latour, B. (2005). *Reassembling the social: An introduction to actor-network-theory*. Oxford University Press.

Leman, M., & Maes, P.-J. (2014). Music perception and embodied music cognition. In D. Fabian, R. Timmers, & E. Schubert (Eds.), *Expressiveness in music performance: Empirical approaches across styles and cultures* (pp. 60–80). Oxford University Press.

Lerdahl, F., & Jackendoff, R. (1983). *A generative theory of tonal music*. MIT Press.

Levitin, D. J., Grahn, J. A., & London, J. (2018). The psychology of music: Rhythm and movement. *Annual Review of Psychology*, *69*, 51–75.

Lewis, G. E. (2004). Improvised music after 1950: Afrological and Eurological perspectives. In D. Fischlin & A. Heble (Eds.), *The other side of nowhere: Jazz, improvisation, and communities in dialogue* (pp. 131–162). Wesleyan University Press.

Lieberman, P. (1986). *The biology and evolution of language*. Harvard University Press.

Lidar, E. (2016). *Timing in symphony orchestras: The relative importance of sight and hearing* [Master's thesis, Chalmers University of Technology]. https://publications.lib.chalmers.se/records/fulltext/245587/245587.pdf

Limb, C. J., & Braun, A. R. (2008). Neural substrates of spontaneous musical performance: An fMRI study of jazz improvisation. *PLOS ONE*, *3*(2), e1679. https://doi.org/10.1371/journal.pone.0001679

Liu, Y., Liu, G., Wei, D., Li, Q., Yuan, G., Wu, S., Wang, G., & Zhao, X. (2018). Effects of musical tempo on musicians' and non-musicians' emotional experience when listening to music. *Frontiers in Psychology*, *9*, 2118.

Livingston, G. (2025). *Performing musical silence: Markers, gestures, and embodiments* [Doctoral dissertation, Leiden University, Academy of Creative and Performing Arts]. Research Catalogue. https://doi.org/10.22501/acpa.1712958

London, J. (2012). *Hearing in time: Psychological aspects of musical meter* (2nd ed.). Oxford University Press.

London, J. (2023). What is musical tempo? In C. Wöllner & J. London (Eds.), *Performing time: Synchrony and temporal flow in music and dance* (pp. 85–93). Oxford University Press. DOI: 10.1093/ oso/ 9780192896254.003.0006

Madison, G., & Merker, B. (2002). On the limits of anisochrony in pulse attribution. *Psychological Research*, *66*(3), 201–207. https://doi.org/10.1007/s00426-001-0085-y

Mahr, N., & Cheprasov, A. (2022). What is Weber's law? *Study.com*.

Manning, F. C., & Schutz, M. (2011). Moving to the beat improves timekeeping in a rhythm perception task. *Canadian Acoustics*, *39*(3), 124–125.

Margulis, E. H. (2007). Musical repetition detection across multiple exposures. *Music Perception*, *24*(5), 485–506.

Martens, P. (2010). The metronome controversy: A re-examination. *Music Theory Spectrum*, *32*(2), 213–227.

Maxwell, J. (1982). *Mockingbird user manual* [Computer software manual]. Xerox Palo Alto Research Center. https://xeroxparcarchive.computerhistory.org/_cd8_/mockingbird/.manual.press%213.pdf

McAuley, J. D. (2010). Tempo and rhythm. In M. R. Jones, R. R. Fay, & A. N. Popper (Eds.), *Music perception* (pp. 165–199). Springer Science + Business Media. https://doi.org/10.1007/978-1-4419-6114-3_6

Mélon, M. (1984). Beethoven's tempi: History, analysis, and performance practice. *Early Music, 12*(3), 322–337.

Meyer, L. B. (1956). *Emotion and meaning in music*. University of Chicago Press.

Mikolajczyk, K. (2019). *Dynamic polytemporality* [Master's thesis, Sydney Conservatorium of Music].

Moore, B. C. J. (2012). *An introduction to the psychology of hearing* (6th ed.). Brill.

Mu:zines. (1989). Coda Music Finale. *mu:zines*. https://www.muzines.co.uk/articles/coda-music-finale/2300

Murail, T. (2005). Spectra and sprites. *Contemporary Music Review, 24*(2–3), 137–147. https://doi.org/10.1080/07494460500154806

Nettl, B. (1974). Thoughts on improvisation: A comparative approach. *The Musical Quarterly, 60*(1), 1–19.

Odermatt, A. J. (2018). *Historical performance practice of the prélude non mesuré and its relationship to recording and performance* (Master of Philosophy thesis). The Australian National University.

Ohriner, M. (2019). Expressive timing. In A. Rehding & S. Rings (Eds.), *The Oxford handbook of critical concepts in music theory* (Chapter 14). Oxford University Press.

Patel, A. D. (2008). *Music, language, and the brain*. Oxford University Press.

Peters, G. (2009). *The philosophy of improvisation*. University of Chicago Press.

Phillips, M. (2022). Music listening and the perception of time: The LEMI model. In M. Phillips & M. Sergeant (Eds.), *Music and time: Psychology, philosophy, practice* (pp. 11–28). Boydell & Brewer.

Pressing, J. (1984). Cognitive processes in improvisation. In W. R. Crozier & A. J. Chapman (Eds.), *Cognitive processes in the perception of art* (Advances in Psychology, Vol. 19, pp. 345–363). Elsevier.

Pressing, J. (1988). Improvisation: Methods and models. In J. A. Sloboda (Ed.), *Generative processes in music: The psychology of performance, improvisation, and composition* (pp. 129–178). Oxford University Press.

Quené, H. (2007). On the just noticeable difference for tempo in speech. *Journal of Phonetics, 35*(3), 353–362. https://doi.org/10.1016/j.wocn.2006.09.001

Rajendran, V. G., Teki, S., & Schnupp, J. W. H. (2018). Temporal processing in audition: Insights from music. *Neuroscience, 389*, 4–18. https://doi.org/10.1016/j.neuroscience.2017.10.041

Rasch, R. A. (1979). Synchronization in performed ensemble music. *Acustica, 43*(1), 121–131.

Reas, E. (2014, July/August). Small animals live in a slow-motion world. *Scientific American Mind, 25*(4), 11.

Repp, B. H. (1992). A constraint on the expressive timing of a melodic gesture: Evidence from performance and aesthetic judgment. *Music Perception, 10*(2), 221–241. https://doi.org/10.2307/40285608

Repp, B. H. (1997). Variations on a theme by Chopin: Relations between perception and performance of rubato. *The Journal of the Acoustical Society of America, 102*(1), 622–639.

Repp, B. H. (1999). Detecting deviations from metronomic timing in music: Effects of perceptual structure on the mental timekeeper. *Perception & Psychophysics, 61*(3), 529–548. https://doi.org/10.3758/BF03211971

Repp, B. H. (2002). The embodiment of musical structure: Effects of musical context on sensorimotor synchronization with complex timing patterns. In W. Prinz & B. Hommel (Eds.), *Common mechanisms in perception and action* (pp. 245–265). Oxford University Press.

Repp, B. H. (2005). Sensorimotor synchronization: A review of the tapping literature. *Psychonomic Bulletin & Review, 12*(6), 969–992. https://doi.org/10.3758/BF03206433

Repp, B. H., & Doggett, R. (2007). Tapping to a very slow beat: A comparison of musicians and nonmusicians. *Music Perception, 24*(4), 367–376. https://doi.org/10.1525/mp.2007.24.4.367

Repp, B. H., & Su, Y.-H. (2013). Sensorimotor synchronization: A review of recent research (2006–2012). *Psychonomic Bulletin & Review, 20*(3), 403–452. https://doi.org/10.3758/s13423-012-0371-2

Rink, J. (Ed.). (1995). *The practice of performance: Studies in musical interpretation*. Cambridge University Press.

Roads, C. (2001). *Microsound*. MIT Press.

Roads, C. (2015). *Composing electronic music: A new aesthetic*. Oxford University Press.

Schick, S. (1994). Developing an interpretive context: Learning Brian Ferneyhough's *Bone Alphabet*. *Perspectives of New Music, 32*(1), 132–153.

Schick, S. (2006). *The percussionist's art: Same bed, different dreams*. University of Rochester Press.

Schnitzler, H.-U., & Kalko, E. K. V. (2001). Echolocation by insect-eating bats. *BioScience, 51*(7), 557–569. https://doi.org/10.1641/0006-3568(2001)051[0557:EBIEB]2.0.CO;2

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. Basic Books.

Schuiling, F. (2019). Notation cultures: Towards an ethnomusicology of notation. *Journal of the Royal Musical Association, 144*(2), 429–458. https://doi.org/10.1080/02690403.2019.1651508

Schuiling, F. (2022). Music as extended agency: On notation and entextualization in improvised music. *Music & Letters, 103*(2), 322–343. https://doi.org/10.1093/ml/gcab109

Schutz, M., & Lipscomb, S. (2007). Hearing gestures, seeing music: Vision influences perceived tone duration. *Perception, 36*(6), 888–897. https://doi.org/10.1068/p5635

Service, T. (2012, September 10). A guide to contemporary music: Brian Ferneyhough. *The Guardian*. https://www.theguardian.com/music/tomserviceblog/2012/sep/10/contemporary-music-guide-brian-ferneyhough

Sloboda, J. A. (1985). *The musical mind: The cognitive psychology of music*. Oxford University Press.

Small, C. (1998). *Musicking: The meanings of performing and listening*. Wesleyan University Press.

Smalley, D. (1997). Spectromorphology: Explaining sound-shapes. *Organised Sound, 2*(2), 107–126. https://doi.org/10.1017/S1355771897009059

van der Steen, M. C., & Keller, P. E. (2013). The Adaptation and Anticipation Model (ADAM) of sensorimotor synchronization. *Frontiers in Human Neuroscience*, 7, 253.

Stockhausen, K. (1959). … How time passes … (C. Cardew, Trans.). *Die Reihe, 3*, 10–40. (Original work published 1957)

Stockhausen, K. (1989). *Stockhausen on music* (R. Maconie, Ed.). Marion Boyars. (Original lecture "Four criteria of electronic music" delivered at the Oxford Union, May 6, 1972)

Sudnow, D. (1978). *Ways of the hand: The organization of improvised conduct*. Harvard University Press.

Tenney, J. (2015). Meta+Hodos and META Meta+Hodos: A phenomenology of twentieth-century musical materials and an approach to the study of form. In L. Polansky, L. Pratt, R. Wannamaker, & M. Winter (Eds.), *From scratch: Writings in music theory* (pp. 13–96). University of Illinois Press. (Original work written 1961)

Thakare, A. E., Mehrotra, R., & Singh, A. (2017). Effect of music tempo on exercise performance and heart rate among young adults. *International Journal of Physiology, Pathophysiology and Pharmacology, 9*(2), 35–39.

Thomas, M. (2000). Nancarrow's "temporal dissonance": Issues of tempo proportions, metric synchrony, and rhythmic strategies. *Perspectives of New Music, 38*(2), 137–186.

Thomas, P. (2022). Midway ambiguities: Disorientation and interpretation in the performance of long-duration music. In M. Phillips (Ed.), *Music and time: Philosophy, psychology, and history* (pp. 97–111). Palgrave Macmillan.

Toiviainen, P., & Snyder, J. S. (2003). Tapping to Bach: Resonance-based modeling of pulse. *Music Perception, 21*(1), 43–80.

Trainor, L. J., Marie, C., Bruce, I. C., & Bidelman, G. M. (2014). Explaining the high voice superiority effect in polyphonic music: Evidence from cortical evoked potentials and peripheral auditory models. *Hearing Research, 308*, 60–70. https://doi.org/10.1016/j.heares.2013.07.014

Vos, P. G. (1973). Waarneming van metrische toonreeksen. Stichting Studentenpers.

Vriezen, S. (2012). Action time. In T. Bissell & S. Simons (Eds.), *Klangzeitort: Zeitfragen in der aktuellen Musik* (pp. 46–50). Universität der Künste Berlin.

Wheatley, J. W. T. C. (2024). *Odd times: The uses of odd-factored time signatures in the works of Thomas Adès and Brian Ferneyhough* [Doctoral dissertation, University of Melbourne].

Wright, R. L., Spurgeon, L. C., & Elliott, M. T. (2014). Stepping to phase-perturbed metronome cues: Multisensory advantage in movement synchrony but not correction. *Frontiers in Human Neuroscience, 8*, Article 724.

Wyschnegradsky, I. (1927), Musique et pansonorité. *La Revue Musicale* 9, 143-52.

Yeats, M. K. (2021). *Control, flexibility, flux and complexity: A timecode-supported approach to polytemporal orchestral composition* [Doctoral dissertation, University of Leeds].

Musical works:

Bach, C. P. E. (1761). Sechs Sonaten fürs Clavier, Wq. 51: Sonata V, Allegro (First edition; composed 1758–1760). George Louis Winter.

Beethoven, L. van. (1989). Symphony No. 9 in D minor, Op. 125 (H. C. Litolff, Ed.) [Composed 1822–1824]. Dover Publications. (Original work published 1826)

Billaudot. (2010). *Salve Regina* (GB8840). Billaudot. https://www.billaudot.com/salve-regina-27.html

Boulez, P. (1984). *Dérive 1*. Universal Edition.

Cage, J. (1952). 4′33″. Peters Edition.

Cage, J. (1988). *Five*. Peters Edition.

Carter, E. (1971). String quartet no. 3. Associated Music Publishers.

Chopin, F. (1840/2021). *Trois nouvelles études* (R. Howat, Ed.). Edition Peters.

Ciconia, J. (c. 1390s/1985). *Le ray au soleyl.* In M. Bent & A. Hallmark (Eds.), The works of Johannes Ciconia (Polyphonic Music of the Fourteenth Century, Vol. 24). Éditions de l'Oiseau-Lyre.

Corigliano, J. (2008). *Winging it*. The Official John Corigliano Website. https://www.johncorigliano.com/works/winging-it

Ghys, F. (2018). *Il va pleuvoir en fin d'après-midi* (Time's Illusion), for ensemble and video. Unpublished manuscript.

Ferneyhough, B. (2001). *Études transcendantales / Intermedio II*. Edition Peters. (Original work composed 1982–1985)

Gordon, M. (1995). *Trance*, for large ensemble. Red Poppy Music.

Gordon, M. (1997). *XY*. Ricordi / Red Poppy Music.

Hummel, J. N. (1808). Clarinet quartet in E-flat major, S. 78.

Inge, L. (2002). *9 Beet Stretch*. NOTAM, Oslo, Norway. https://www.9beet2.com/leif-inge/

Ives, C. (1906/1973). *Central Park in the Dark: No. 1* of "Three outdoor scenes". Boelke-Bomart.

Ives, C. (1908/ca. 1935). *The unanswered question*.

Ives, C. (1915/1947). *Piano sonata no. 2 "Concord, Mass., 1840–60"*. Associated Music Publishers.

Jarrett, K. (1991). The Köln Concert (Y. Kishinami & K. Yamashita, Transcribers). Schott Music. (Original work recorded 1975)

Kubisch, C. (1974). *Identikit (Divertimento)*, for five pianists at one piano and tapes. Unpublished score.

Kyriakides, Y. (2011). *Wavespace*, for mixed octet, live electronics and live video. Donemus.

Ligeti, G. (1962). *Poème symphonique*, for 100 metronomes. Schott Music.

Mozart, W. A. (1781/1962). Quartet for oboe, violin, viola and violoncello in F major, K. 370 (368b) [Urtext study score]. Bärenreiter.

Nancarrow, C. (1951–1960/1985). *Study no. 9*, for player piano. In Collected studies for player piano (Vol. 6). Soundings Press.

Nancarrow, C. (1961/1984). *Study no. 21* "Canon X", for player-piano. In Collected studies for player piano (Vol. 5). Soundings Press.

Nielsen, C. (1920–1922). Symphony no. 5, op. 50. Edition Wilhelm Hansen.

Nova, R. (2010–2014). *Primes Seventeen*. Casa Ricordi.

Ravel, M. (1912). *Daphnis et Chloé, Suite No. 2*. Durand.

Reicha, A. (1803/2011). Fugue no. 30, from 36 fugues for piano, op. 36. Bärenreiter.

Schoenberg, A. (1911). *Sechs kleine Klavierstücke*, Op. 19. Universal Edition.

Sinan, M. (2020). *At first*, for Djiguiya Orchestra Bamako, Marc Sinan Company, Neue Vocalsolisten Stuttgart, choreographer and video. Marc Sinan Company.

Sorabji, K. (1940–1944/2007). Transcendental study no. 71, from 100 transcendental studies (A. Abercrombie, R. Howat, & M. Smith, Eds.). Sorabji Archive.

Stockhausen, K. (1960). *Kontakte* für elektronische Klänge, Klavier und Schlagzeug. Universal Edition.

Stockhausen, K. (2009). *Klavierstücke I–IV*. Universal Edition. (Original work published 1952)

Stravinsky, I. (1947). *Petrushka*. Boosey & Hawkes. (Original work published 1911)

Stravinsky, I. (1953). *Septet*. Boosey & Hawkes.

Thomas, A. R. (2005). *Twitter-Machines* [Etude No. 6 of Piano Etudes (1996–2005)]. G. Schirmer.

Thoorens, V. (Arr.). (n.d.). *Le Ray au Soleyl* [Musical arrangement of the work by Johannes Ciconia, ca. 1390s]. MuseScore. https://musescore.com/user/34164491/scores/6077903

Vitali, G. B. (1689/c. 2000). "Balletto per zwei violini e violone", from *Artificii musicali*, op. 13. Ricordi.

Xenakis, I. (1957). *Achorripsis*. Universal Edition.

Xenakis, I. (1984). *Thallein*. Boosey & Hawkes / Éditions Salabert.

Own music works:

Alap (2005). Donemus. Performers: Axyz Ensemble, Kristina Fuchs (voice), Susanna Borsch (tenor recorder), Ned McGowan (flute).

McGowan, N., & Manjunath, B. C. *Benson Town* (2016). Unpublished musical score. Performers: Ned McGowan (contrabass flute), B. C. Manjunath (mridangam).

Building Music (2013). Donemus. Performers: David Kweksilber Big Band, Jennifer van de Hart (vocalist).

Concerto for Indian Percussion (2022). Donemus. Performers: New European Ensemble, B. C. Manjunath (Indian percussion).

Cycle Games 1 (2019). Donemus. Performers: Ned McGowan (vocal percussion), B. C. Manjunath (vocal percussion).

For Bob (2015). Donemus. Performers (version 1, mixed instruments): Samuel Vriezen (piano), Keiko Shichijo (piano), David Dramm (voice), Alfrun Schmid (voice), Helena Winkelman (violin), Anne LaBerge (flute), Diamanda Dramm (violin), Elizbeth Smalt (viola), Benjamin Marquise Gilmore (violin), Hannah Shaw (viola), Ned McGowan (conductor).

For Bob (2015). Donemus. Performers (version 2, flutes): Anne LaBerge (flute), Eric Lamb Rummel (flute), Angelika Sheridan (bass flute), Katie Spencer (alto flute), Hannah Reardon-Smith (flute), Evelin Degen (flute), Rob Van Dord (flute), Felicia Van Den End (flute), Camilla Hoitenga (flute), Ned McGowan (contrabass flute).

For Bob (2015). Donemus. Performers (version 3, Jerboah): Jerboah (ensemble), Sarah Jeffery (alto recorder), Guillermo Celano (electric guitar), Dodó Kis (contrabass recorder), Marcos Baggiani (glockenspiel), Brechtje van Dijk (voice), Ned McGowan (contrabass flute).

For Bob (2015). Donemus. Performers (version 4, Fokker organ): Ned McGowan (flute; contrabass flute; Fokker organ), Gregory Oakes (clarinet).

Garden of iniquitous creatures (2016). Donemus. Performers: Robert Fleitz (piano), Nathalie Joachim (flute), Benjamin Mitchell (clarinet), Jeff Stern (drum set), Kate Outterbridge (violin), Aaron Wolff (cello).

Hydraulic principles (2012). Donemus. Performer: Kasper Janse, pianola.

Moonrise (1998). Donemus. Performer: Ned McGowan (flute).

Plutoid (2008). Donemus. Performers: Ned McGowan (flute), Stephie Buttrich (vocals), Gijs Levelt (trumpet), Susanna Borsch (alto recorder), Ere Lievonen (piano).

Rhythmic etudes – Book one (2014). [Includes "The Speed of Time"]. Donemus. Performer: Laurens de Boer (piano).

Rickshaw Zip (2015). Donemus. Performers: Ilonka Kolthof (piccolo), Ralph van Raat (piano).

Six pièces mécaniques (2012). Donemus. Performers: Calefax Reed Quintet, Eric Vloeimans (trumpet).

Sound becomes visible in the form of radiance (2003). Donemus. Performers: Pittsburgh New Music Ensemble.

Stone Soup (2001). Donemus. Performers: Ned McGowan (flute), Gijs Levelt (trumpet), Tobias Klein (bass clarinet), Oene van Geel (violin), Mark Haanstra (electric bass), B. C. Manjunath (mridangam), Srihari (ghatam).

Sydney Polypulse (2019). Donemus. Performers: Eleni Giovanis (violin), Lydia Kordonia (cello), Antoni Ingles (piano), Elena Herrero (bass clarinet), Ines Lacerda (percussion), Ned McGowan (flute).

Tools (2003). [Includes "Telescopic Ladder," "Pneumatic Screed," "Pneumatic Screed Extension Handle," and "Pneumatic Screed Extension Handle Cover"]. Donemus. Performers: Ned McGowan (flute), Gijs Levelt (trumpet), Susanna Borsch (alto recorder), Ere Lievonen (piano).

Torrent (2011). Donemus. Performer (version 1): Ned McGowan (flute).

Torrent (2011). Donemus. Performer (versions 2 and 3): Reiko Manabe (flute).

Torrent (2011). Donemus. Performer (version 4): Kenneth Cox (flute).

Urban Turban (2001). Donemus. Performers: Claire Edwards (marimba), Niels Meliefste (marimba).

Volt (2015). Donemus. Performer: Diamanda Dramm (violin).

Workshop (2004). Donemus. Performer: Susanna Borsch (alto recorder).

Abstract

This dissertation investigates musical speed: what it is, how it is perceived, and how it can be explored within compositional, improvisational, and performance practice. Drawing on several decades of work as a composer, flutist, and improviser, I argue that speed in music is far richer and more nuanced than tempo alone suggests. I propose a working definition of speed as the rate of perceptual events in time, functioning across multiple, independent yet concurrent timescales, and co-constructed by the music, performer, environment, and listener. Rather than a single parameter such as tempo or rhythmic grid, speed emerges through the interaction of simultaneous rates, including pulse, event density, grouping, and musical change.

The dissertation builds this framework through five interlocking perspectives. The first examines thresholds of speed through creative reworkings of Beethoven's *Ninth Symphony* at radically different speeds, demonstrating how temporal compression and expansion transform musical identity at boundaries where rhythm becomes pitch, gesture becomes texture, and structure becomes instantaneous gestalt. The second addresses temporal resolution, exploring the biological limits of perception and their implications for musical hearing. The third investigates density and motion, showing that numerical note density cannot be equated with perceived speed. It is the rate of change in density, together with the distribution, grouping, and shaping of events, that most strongly affects the perception of musical motion. The fourth strand engages with smooth and striated time. Drawing on Pierre Boulez, Gilles Deleuze and Félix Guattari, and Gérard Grisey, it proposes that temporal modes operate along a continuum rather than as a binary opposition. The fifth draws on Michelle Phillips' Listener-Environment-Musical Stimulus-Interaction (LEMI) model and Donna Haraway's theory of situated knowledge to frame speed as a relational phenomenon that arises from shifting constellations of embodied, environmental, cognitive, and material conditions.

These conceptual foundations are then applied through three focused investigations. An examination of tuplets (subdivisions of the beat) shows them to be tools for shaping perceived speed within the notated grid: by altering subdivision, they can reshape the identity of musical material, and in nested tuplet writing (tuplets within tuplets), they can paradoxically generate an impression of smooth time from extreme striated precision. The second investigation extends into polytempo music, where my compositions *Building Music*, *For Bob*, and *Sydney Polypulse* serve as laboratories for examining how multiple concurrent temporalities are constructed and negotiated in performance, with particular attention to the role of haptic metronomes and the management of controlled asynchrony. Finally, the dissertation presents a case study of my solo flute piece *Torrent*, which originated as a maximal-speed improvisation and was later fixed through transcription. In this case study I propose a "speed of creation" framework that treats improvisation and composition as points on a continuum of decision-making speed and reflective latitude rather than as opposed categories.

The dissertation integrates artistic creation, theoretical reflection, scientific literature, and situated performance experience. It demonstrates that musical speed is relational, arising through interactions between musical events, bodily motion, cognition, and context. By reframing speed as both form-bearing and meaning-bearing, the research offers practical and theoretical insights for composers, performers, teachers, scholars, and technology developers, and it argues for recognizing speed as a central dimension of musical life.

Samenvatting

Deze dissertatie onderzoekt snelheid in muziek: wat het is, hoe het wordt waargenomen, en hoe het kan worden verkend binnen compositie-, improvisatie- en uitvoeringspraktijk. Op basis van mijn werk als componist, fluitist en improvisator gedurende enkele decennia betoog ik dat snelheid in muziek veel rijker en genuanceerder is dan tempo alleen doet vermoeden. Ik stel een werkdefinitie voor van snelheid als de mate van perceptuele gebeurtenissen in de tijd, werkzaam op meerdere onafhankelijke maar gelijktijdige tijdschalen, en geconstrueerd door het samenspel van muziek, uitvoerder, omgeving en luisteraar. In plaats van een enkele parameter zoals tempo of metrisch raster ontstaat snelheid uit de interactie van gelijktijdige processen, waaronder puls, gebeurtenisdichtheid, groepering en muzikale verandering.
Het proefschrift bouwt een nieuw begrip van snelheid op aan de hand van vijf met elkaar verweven perspectieven. Middels het eerste perspectief onderzoek ik de drempels van snelheid en laat door middel van creatieve bewerkingen van Beethovens *Negende Symfonie* op radicaal verschillende snelheden zien hoe temporele compressie en expansie de muzikale identiteit transformeren op perceptuele grenzen waar ritme overgaat in toonhoogte, gebaar in textuur, en structuur in een onmiddellijke gestalt. In het tweede perspectief ga ik in op temporele resolutie en verken de biologische grenzen van waarneming en hun implicaties voor het muzikale gehoor. Ten derde onderzoek ik dichtheid en beweging en toont aan dat numerieke nootdichtheid niet gelijkgesteld kan worden aan waargenomen snelheid. De mate van verandering in dichtheid - samen met de wijze waarop gebeurtenissen worden verdeeld, gegroepeerd en vormgegeven - is het sterkst van invloed op de ervaring van muzikale beweging. Het vierde perspectief gaat in op het verschil tussen zogenaamde vloeiende en gegroefde tijd (respectievelijk *lisse* en *strié*), en bouwt voort op het werk van Pierre Boulez, Gilles Deleuze en Félix Guattari, Gérard Grisey en Brian Hulse. Hier stel ik dat temporele modi functioneren als een continuüm in plaats van een binaire tegenstelling. Het vijfde perspectief maakt gebruik van het Listener-Environment-Musical Stimulus-Interaction (LEMI)-model van Michelle Phillips en Donna Haraway's theorie van gesitueerde kennis om snelheid te begrijpen als een relationeel fenomeen dat voortkomt uit wisselende constellaties van lichamelijke, omgevings-, cognitieve en materiële condities.

Deze conceptuele basis wordt vervolgens toegepast in drie gerichte onderzoeken. Een analyse van tuplets (onderverdelingen van de maatslag) toont aan dat dit krachtige middelen zijn om waargenomen snelheid binnen het genoteerde grid te beïnvloeden en te sturen: door de onderverdeling te wijzigen kunnen zij de identiteit van muzikaal materiaal transformeren, en in geneste tuplets (tuplets binnen tuplets) kunnen zij op bijna paradoxale wijze een indruk van vloeiende tijd genereren vanuit extreme gegroefde precisie. Het onderzoek strekt zich vervolgens uit naar polytempo muziek (muziek waarin meerdere tempi gelijktijdig klinken). Mijn composities *Building Music*, *For Bob* en *Sydney Polypulse* dienen als laboratoria om te onderzoeken hoe meerdere gelijktijdige temporaliteiten worden geconstrueerd en in de uitvoeringspraktijk op elkaar afgestemd. Bijzondere aandacht gaat hier uit naar de rol van haptische metronomen en het beheersen van gecontroleerde asynchronie. Ten slotte introduceer ik mijn solo fluitstuk *Torrent*, dat is ontstaan als een improvisatie op maximale snelheid, die vervolgens door middel van transcriptie is vastgelegd. In deze casestudy stel ik een 'creatie-snelheid'-kader voor dat improvisatie en compositie beschouwt als punten op een continuüm van beslissings- en reflectieve snelheid, in plaats van ze te beschouwen als tegenover elkaar gestelde categorieën.

In het proefschrift breng ik artistieke creatie, theoretische reflectie, wetenschappelijke literatuurstudie en gesitueerde uitvoeringservaringen samen. Het onderzoek toont aan dat muzikale snelheid relationeel is: zij ontstaat uit relaties tussen muzikale gebeurtenissen, lichamelijke bewegingen, en reflecties en contexten. Door snelheid te herdefiniëren als vormgevend en betekenisgevend, biedt het onderzoek praktische en theoretische inzichten voor componisten, uitvoerders, docenten, onderzoekers en technologieontwikkelaars, en pleit het voor de erkenning van snelheid als een centrale dimensie van muziek maken.

Curriculum Vitae

Ned McGowan was born on February 28, 1970, in Pittsburgh, Pennsylvania, United States. He holds a High School Diploma in flute performance from Interlochen Arts Academy (1988), a Bachelor of Music degree in flute performance from the Cleveland Institute of Music and Case Western Reserve University (1992), a Master of Music degree in flute performance from the San Francisco Conservatory of Music (1994), and a Bachelor of Music degree in composition from the Royal Conservatory in The Hague (2003).

Following the completion of his academic education, McGowan developed an international career as a composer, flutist, teacher, and researcher. His compositions have been performed by orchestras, ensembles, and soloists in Europe, North and South America, Asia, and Australia, and have been presented in venues including Carnegie Hall, the Concertgebouw, and the Purcell Room. He has received multiple prizes and distinctions, including the Henriette Bosmans Prize (2003), the Harvey Gaul Composition Competition prize (2009), and several awards from the National Flute Association (2016, 2018). As a performer, he specializes in the contrabass flute and has composed and premiered concertos for the instrument, contributing to the contemporary repertoire for low flute. His artistic practice is characterized by a sustained focus on rhythm, intercultural collaboration, and the exploration of musical temporality.

McGowan is a teacher of composition at the HKU Utrecht Conservatory, where he serves as Chair of the Master's and Bachelor's Artistic Research curriculum and teaches Artistic Research Skills and Advanced Rhythm and Pulse. He has also worked as an artistic research coach and advisor at Codarts University of the Arts and at Fontys Academy of Music and Performing Arts. In addition to his teaching and compositional activities, he has lectured and given workshops internationally.

His PhD research, entitled *Speed in Music*, was conducted at Leiden University within the DocARTES program in collaboration with the Orpheus Institute in Ghent (2016–2026). The research was supported by the Netherlands Organisation for Scientific Research (NWO) and Fontys Academy of Music and Performing Arts.