Harmony inside harmony

just intonation as a perceptual praxis

and as an organizing compositional principle

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Contents

Abstract

This research looks at how the combined knowledge of structure and perception of just intonation (JI) can work together with other musical approaches to organize musical material for compositions, both for solo guitar and for ensembles. The research has three main goals. First, it aims at showing the interconnectedness of JI theory and perception, and how both are manifestations of the *structure* of JI. Second, the research aims to document and present personalized methods of approaching the guitar in the context of JI music. Finally, it aims to establish the case that JI music involves a unique mode of listening that in its ideal form is shared between listeners and musicians when such material is performed. Introducing my research, Chapter 1 and 2 cover the overarching elements and the context of the research. The succeeding three chapters (3, 4 and 5) comprise the main body of the text. Chapter 3 is purely theoretical, where key aspects of JI are illuminated in their own terms. Chapter 4 discusses case studies, where musical pieces are analyzed through their JI elements – theoretically, perceptually and practically. In Chapter 5 I argue for the existence of a unique mode of listening shared between performers and listeners when JI music is realized. Finally, the brief, concluding Chapter 6 concerns the results of my research and its implications for future research and praxis. The main research materials are four of my own compositions serving as case studies, two of which are analyzed comparatively with works by composers Catherine Lamb and Marc Sabat. Through harmonic analysis of selected sections, the research aims at showing how these pieces exemplify both distinct and shared methods of utilizing JI harmony in composition, and how realizing them are part of a *perceptually rooted musical praxis*. In the introduction I make a distinction between overarching research methods and musical methods. The research methods both encompass theoretical descriptions of JI concepts, and analysis of JI elements as they occur in musical context drawing on the case studies. Musical methods include ways of composing pieces in JI, where improvisation or open elements are implemented.

1 - Introduction

1.1. Just intonation – harmony inside harmony

One of the early and formative experiences I had with *just intonation* (JI) was interpreting Catherine Lamb's solo guitar piece *Point/Wave* (Lamb, 2015) in 2016. The first time I was tuning the guitar's *scordatura* (tuning) for this piece, using a tuner application showing exact frequencies, and then striking the chord of the open strings while listening to the glistening sound, I was completely mesmerized. The sound struck me as electric or with more of a physical character than how I was used to hearing harmony. This and similar experiences around the same time inspired a new personal path. From then and until today all the music I have been engaged in creatively has related to JI in some way. Taking my own musical praxis as a starting point, this research is about the dynamics of just intonation as a perceptual musical praxis, and the ways in which a union of theoretical and practical knowledge serve as an *organizing principle* both for musical material and the listening experience inherent to JI. I will argue that this listening experience is shared between performer(s) and listener(s), that it is grounded in perceptual facts creating a transparent listening space, and, lastly, that it is unique to JI music. In the article about just intonation at Grove Music Online, the author Mark Lindley introduces just intonation as follows:

> When pitch can be intoned with a modicum of flexibility, the term 'just intonation' refers to the consistent use of harmonic intervals tuned so pure that they do not beat [...] (Lindley, 2001, p. 1).

Lindley points out that justly intonated intervals *do not beat*. In my view, the absence of so-called beating (or *interference*), is the most striking sonic quality of just intonation as such. It evokes a soothing or relaxing, yet energetic feeling. Furthermore, my dedication to JI comes from the experience of its potential to open a compelling grade of detail inside harmony – a *harmony inside harmony* as the title of this thesis says. Timbral clarity, intensified overtones and pulsating vibrancy are all descriptions of the phenomenology of JI sound. My musical praxis documented here is part of two fields of music making. Firstly, it

can be described as the tripart role of the *composer-performer-improviser*. I am using this term to refer to a holistic attitude to music making, where the artist creates through both improvisational and compositional means, and where they realize their own music. Secondly, it belongs to the field of musical composition in just intonation. This research is situated in the intersection of these two fields, where I, as a guitar-playing composer-performer-improviser engage with JI compositional strategies, investigating the interconnections between the two approaches.

Examples of artists in the first category which are doing work in the framework of artistic research include Magda Mayas, extending techniques and timbres on the piano (Mayas, 2019) and Egil Kalman, whose current research as a PhD fellow at UiA (*Universitet i Agder*) is another example of an artistic research project drawing on JI and the role of the performer-composer-improviser, in this instance focusing on Scandinavian folk music and modular synthesis.

1.2. Research questions and definitions

This thesis is dedicated to a certain artistic praxis with JI – a praxis comprising a totality of instrumental practice, composing, theory and perception. In this section I will present the research questions, define their key terms, and analyze the connections between them.

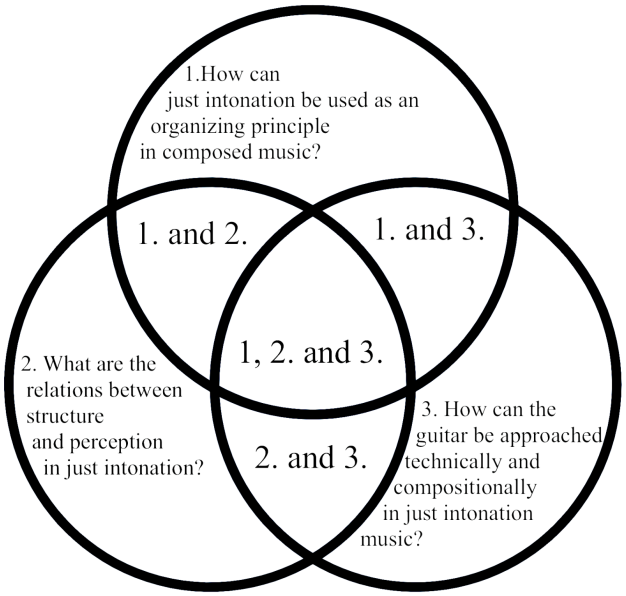
This research is guided by three research questions:

1. How can just intonation be used as an organizing principle in composed music?
2. What are the relations between structure and perception in just intonation?
3. How can the guitar be approached technically and compositionally in just intonation music?

JI has certain intrinsic elements with which it *conditions* (as a verb), i.e. limits as well as enables, organizational possibilities within harmony. Its *conditions* (as a noun) are the elements that might serve as an *organizing principle* for composition. The kind of *composed music* that this research focuses on is characterized by the following properties. Firstly, it is a

kind of minimalistic and experimental music in JI based on composition, where improvisational elements are implemented. Secondly, it involves real-time on-ear tuning [1]. Finally, it favors sustained sound and/or repetitive elements. *Organizing principle* refers to the ability of JI to function as such in composition, while the term *structure* has a more complex meaning. It refers, *ideally*, to the inherent structural properties of JI *in itself*. However, *practically*, it refers to the manifold of conceptual entry points in our understanding of JI, and is hence closely tied to JI *theory*. While using the term *theory* instead of *structure* would render an almost identical intention, *structure* is favored here, as it succeeds in referring to the overarching realm of structural properties of JI, and not only our theorizing about it. Additionally, the term is more useful because we want to show the relations between structure and perception – how the structure is perceived, and how the perception is structured, rather than how *theory* is perceived and vice versa. The third research question is addressed solely through the case studies. Of the four original compositions discussed, the guitar is integral to three of them. The artistic praxis substantiating this research consists of interconnected and overlapping elements. Posed as questions, these elements constitute the three research questions, and the connections between them can be illustrated with a venn-diagram (fig. 1):

[1] Exceptions are Catherine Lamb's piece *Point/Wave* and my piece *Six Moving Guitars,* both of which are based on JI guitar tunings tuned beforehand and involve no real-time tuning. These pieces are anyhow relevant because they exemplify the topics of the research question with other JI-means than on-ear tuning, and hence they contribute to showing the wider variety of approaches available in the field.



Question 1 and 2 overlap when we discuss **the interconnectedness of perceptual and structural qualities of JI** and its implications on **the organizational conditions that JI places on composition**, or vice versa.

Question 1 and 3 overlap when we discuss **the conditions that JI places on composition** and their implications on **the conditions for composition and/or realization of JI on/for guitar**, or vice versa.

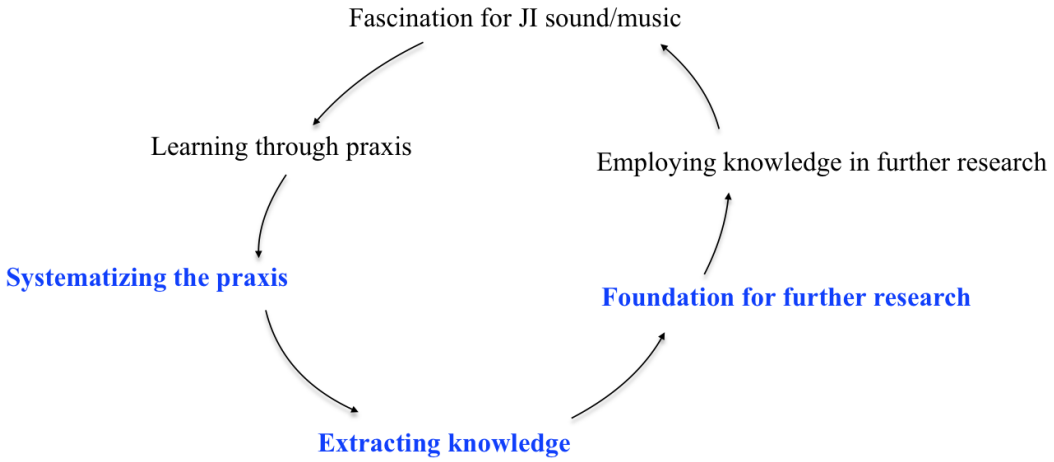
Question 2 and 3 overlap when we discuss **the interconnectedness of perceptual and structural qualities of JI** and its implications on **the conditions for composition and/or realization of JI on/for guitar**, or vice versa.

All three questions overlap when we discuss **the interconnectedness of perceptual and structural qualities of JI** and its totality of implications on **the organizational conditions that JI places on composition** and **the conditions for composition and/or realization of JI on/for guitar.**

The case studies will be evaluated on the background of the research questions and the relevant interconnections outlined above.

1.3. The nature of research, and goals

The nature of research is to find connections that are not self-evident. In other words, to come to conclusions that are not already embedded into the premises. On this background we can ask: what is embedded in my research questions and which connections are yet to be proven? Let us look at what exactly the three research questions presupposes and what they do not. They all presuppose that JI *can* be used as an organizing principle.., that there *are* connections between structure and perception in JI, and that it *is* possible to realize JI music on guitar – all of which are key elements of the praxis documented here. In presupposing the *existence* of these key elements, and asking *how* they work, their existence is also proven as a consequence of exemplifying their *realities* in a musical praxis. The thesis as such consists in describing, analyzing and systematizing the elements constituting these facts, in finding and demonstrating connections between them, ultimately addressing the questions about JI as compositional organization, as structure and perception, and as conditioning approaches to the guitar. Hopefully, the answers can lead to new knowledge that is both significant in itself and of value to further research. The illustration below (fig. 2) shows the process this research is part of, and its nature as a cyclic process. The development through each stage bears witness to the *process*, eventually returning to the "top", where the fascination for JI sound/music with new knowledge and experience can be used as a returning, yet revitalized starting point for a *continuous* process of learning and internalizing aspects of JI music making. Importantly, the stages belonging specifically to *this* research are marked in blue. We see that its scope and aim first and foremost concern systematizing and extracting new knowledge from an already developed body of musical work.



With this cyclic movement, the *hermeneutic* nature of this process becomes evident, since knowledge is not treated as a linear movement, but as a cyclic process, where ever-changing interpretations come into focus through these repeating cyclic processes. Stanford Encyclopedia of Philosophy's article on hermeneutics states:

> […] the concept of the hermeneutical circle signifies that, in interpretive experience, a new understanding is achieved not on the basis of already securely founded beliefs. Instead, a new understanding is achieved through renewed interpretive attention to further possible meanings of those presuppositions which, sometimes tacitly, inform the understanding that we already have (Theodore, 2021)

This explanation fits the processes my research is part of. Rather than starting with an established body of knowledge, it starts with an experience of sound, and through processes of interpreting this experience and its associated propositional and *tacit* knowledge, it extracts new knowledge which subsequently impacts the musical experience, a process which then repeats cyclically and without end.

The terms *practice* and *praxis* and how they are used in this thesis calls for some clarification. The former refers to individual *practical* activities, such as rehearsing, playing and composing, whereas the latter refers to the total field of all practical and theoretical dimensions involved in it. **Learning through praxis** and **systematizing the praxis** hence refer to learning and systematizing a unity of theory and practice with JI. To sum up – in

aiming for coherent and illuminating answers to the research questions, this text intends to establish a foundation of facts concerning JI as a perceptual praxis; a foundation from which future research can continue to discover connections to other facets of this praxis, such as social dynamics, listening attitudes, ethics etc.

1.4. Theoretical perspectives and literature

In documenting a personal artistic body of work, this master thesis fits into the tradition of *Artistic research* (AR). The Dutch philosopher and music theorist Henk Borgdorff (1954 -) is an important contributor to the debate on AR. Drawing from a model introduced by educationalist and writer Christopher Frayling in his 1993 article *Research in Art and Design* (Frayling, 1993) where Frayling differentiates between research 'into art', 'for art' and 'through art', Borgdorff establishes a similar trichotomy consisting of research *on* the arts, *for* the arts and *in* the arts (Borgdorff, 2007, p.6). While my research primarily fits the label '*in* the arts', it resonates with all three stances. It is '*on* the arts' when I describe theoretical aspects of JI, it is '*for* the arts' when I describe certain ways of realizing a musical task, and it is '*in* the arts' when I play and compose. This trichotomy is useful, because it provides a measurement enabling me to consciously discern the varying positions I take on in conducting this research.

Another relevant tripart categorization in Borgdorff's paper is dividing AR into *process, object* and *context.* In my research, the objects are the four compositions presented as case studies, the processes are the methods for developing, composing and realizing them (Chapter 4), while the context comprises the references to other music in the same field and the ideas about listening (Chapter 5).

1.5. Resources

I will make a distinction between internal resources (e.g. my own compositions) and external resources (literature, music). Regarding external resources, this research takes Borgdorff's two trichotomies outlined above as a starting point. Other external resources include two pieces by other composers analyzed comparatively with my own pieces, published interviews

with composers, literature about JI and other relevant musical topics. The internal resources include my own theoretical and practical knowledge about JI as well as the four case studies.

1.6. Methods

The methodology is divided into two levels: *theoretical* methods and *musical* methods, both of which I will discuss in the following.

1. Theoretical methods:

In this research I employ a practice-based research method, since the objects, processes and context of my own musical practice are scrutinized. There are two methodological stages at play at this level based on *descriptive* and *analytic* writing. Firstly, I will *describe* key theoretical aspects of JI. This is a joint venture between research *for*, *on* and *in* the arts. It is *for* and *on* the arts when I describe sonic and musical principles that are not exclusive to my own musical creation, but belong to a larger field of musical praxis. It is simultaneously *in* the arts, because what I choose to describe and the ways in which I describe them are mirroring my personal resources for musical creation. Secondly, having described key theoretical aspects, I will *analyze* the compositions in my case studies, guided by the research questions. To give an example, the most relevant kind of analysis for this end is analysis of the harmonic structural elements in each case study, their role in organizing the music, and the role of the guitar.

This is the application of the theoretical methods, following the chronology of the text:

- **Describing** the field of music that this research is about (Chapter 2)
- **Describing**, from a **theoretical** standpoint, the key **sonic** aspects of JI with my own knowledge of it as a basis (Chapter 3)
- **Describing**, from a **theoretical** standpoint, the **structural** aspects of JI and how it is understood as numerical/rational relations (Chapter 3)
- **Analyzing,** both from a theoretical and a perceptual standpoint, how to conceptually bridge the **sonic** and **structural** aspects of JI (Chapters 3, 4 and 5)

- **Analyzing,** both from a theoretical and perceptual standpoint, in which ways the case studies exemplify JI as an organizing principle, interconnectedness of JI perception and structure, the relations between these elements and the guitar (Chapter 4)
- **Describing** how the findings from the preceding chapters can be used in establishing the view that JI entails a shared mode of listening between musicians and audience (Chapter 5)

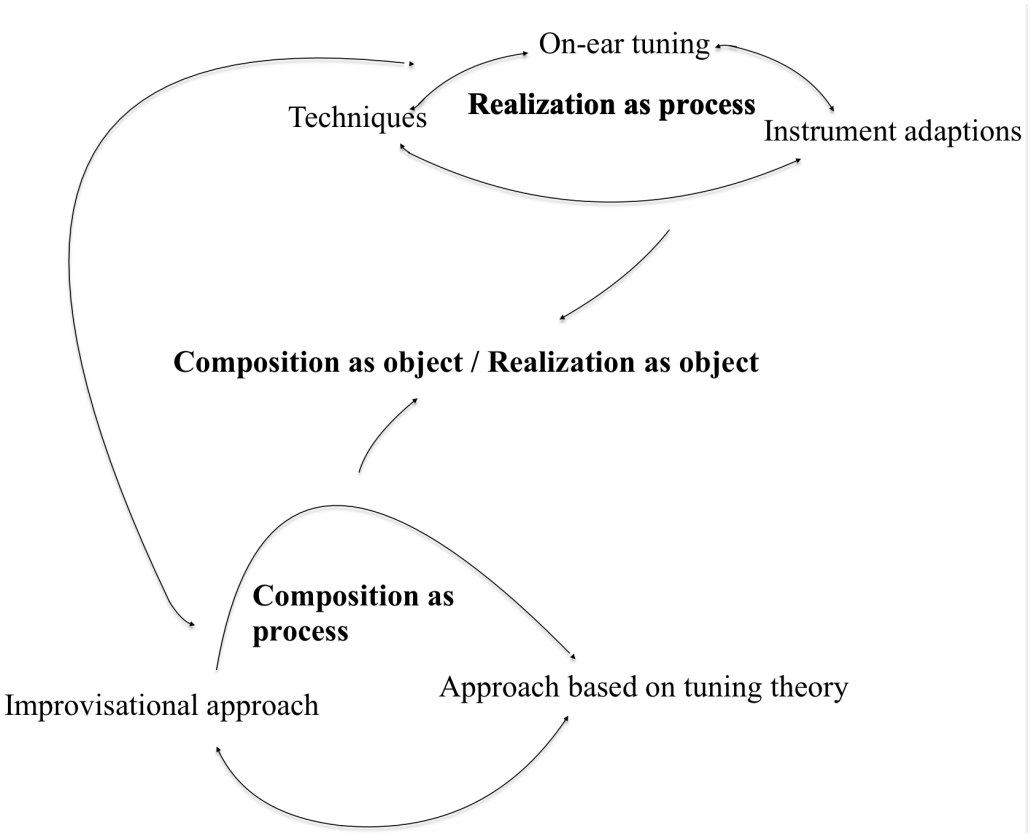
With 'description' I mean illuminating aspects through consensual/established theories/facts. With 'analysis' I mean an undertaking that employs description as a means of connecting seemingly unconnected elements, or showing how certain premises lead to certain conclusions relating to the research questions.

2. Musical methods:

The main musical methods in this research are **composing** and **realizing** music, and they are each constituted of underlying methods, which will be explained shortly. These main methods draw on Borgdorff's distinction between object, process and context. Relative to each artistic endeavor, we can see *process* and *object* as points on a finite line starting in process and ending in object, **or** as a repeating cycle of the two. In this movement the *verb* turns into a *noun*: composing becomes composition and realizing turns into realization. The *context* view in this research encompasses the conditions that are external to me as a composer/performer, e.g. when the idea of a mode of listening shared between audience and musicians are discussed in chapter 5.

As mentioned, there are underlying constitutive methods belonging to both composition and realization of music in this research, including interconnections between them. Within **composition** as a method in this research, there is an **improvisational** approach, where improvisation is used to generate compositional material, and there is an **approach based on tuning theory**, where experience and knowledge about JI tuning theory is used to generate compositional material. Both these belong to **composition as process**, and they can be used separately or in combination to produce a musical composition, or **composition as 'object'.** Regarding **realization** as a method, it involves the underlying methods of

developing and utilizing **techniques** and/or **instrument adaptations** to make the guitar suitable for the particular JI tasks in question, as well as **on-ear tuning.** All these belong to **realization as process**. Composition and realization as processes are influencing each other and eventually combining to create a composition as object (score), and a realization (of the composition) as object (concert, recording. etc.). The following diagram (fig.3) illustrates the methods as process/object, with arrows illustrating their influences on each other:



1.7. Organization of the thesis

1. Introduction: The introductory parts cover a brief introduction to JI and outlines the structural elements of the research.

2. A contextualization of an approach to JI music: This chapter aims to contextualize the music that this research is about - through a personal entry point regarding my own introduction to JI, through ideas about listening and social interaction from the *Wandelweiser*

collective, by clarifying the *approach of the composer-performer,* and by showing its connection to two musical traditions – American experimentalism and North-Indian Dhrupad tradition.

3. Key elements of JI: Guided by research question 1 and 2 I will describe the theoretical and sonic aspects of JI integral to the artistic work that this research examines.

4. Case studies: The four case studies are chosen as they each exemplify different ways of organizing music through JI, different theoretical aspects of it, and different approaches to the guitar. Two other pieces, by composers Catherine Lamb and Marc Sabat, are used in comparative analysis with two of the original compositions.
Referencing the research strategy (1.5.), these are internal and external resources, respectively.

5. Experiential, social and human aspects of just intonation: In this chapter we will employ our findings about particularly perceptual aspects of JI and extend them into the topics of experience and social interaction. More specifically, we will raise the claim that there is an inherent and unique mode of listening inherent to JI that is shared between musicians and the audience.

6. Conclusions and ways ahead: In the last part we will extract further conclusions from the research. We will also discuss possible questions or topics for other research projects building on, or related to this research.

2 - A contextualization of an approach to JI music

Musical practice is both subjective and intersubjective, it is as inward as a feeling or a thought process, and as outward as a public speech. Music both gives us deep subjective experiences and it is binding us together in social experiences and communities. In this chapter I will contextualize the field of music that this research is about, both through personal experiences and through the wider perspective of the communities and the history that it exists within.

2.1. My encounter and path with just intonation

I will start this second chapter of the thesis describing my own introduction to just intonation. At the time of my JI first discoveries (around 2016) I already had an extensive *improvisational* praxis based on sustained tones realized on an acoustic guitar that I played in *idiosyncratic* ways – with a ruler, violin bow or other preparations enabling the strings to sound continuously and indefinitely. Acoustic phenomena such as *beating*, *difference tones* etc., became a main musical focus. However, the methods for working with such a focus, both alone and in collaboration with others, and most notably in the duo *Pip* with trumpet player Torstein Lavik Larsen, were of an unsystematized nature, comprising an intuitive approach. In this music we were nevertheless engaged with the physical aspects of sustained tones – a focus shared with the JI music discussed in this research. When I discovered JI the guitar became an important work tool for learning. Despite the fact that guitars are designed for *tempered* tonalities, they are in many ways easily adaptable to encompass microtonality when approached in unconventional ways. Guitars have tuning pegs easily at hand, and in treating the various open string combinations as chords, thus approaching the guitar more as a harp, I started implementing real-time tuning of the strings as a method for learning and creating JI music. Relating this to the present research, I was working simultaneously with research question 2 and 3, without having formulated them as such yet. Different *idiosyncratic* JI-approaches to the guitar were developed, and through this shared focus between creating and learning, and between the *sonic* and *theoretical* aspects of JI, interconnections between all these aspects were explored.

2.2. Influence from *Wandelweiser*

While the main themes of this thesis revolve around the core elements in JI praxis, one of the main aims is to solidify knowledge of this into a foundation that has consequences beyond the aesthetic aspects of JI, into the areas of phenomenological, social and ethical concerns. For the purpose of contextualization of these aspects, this section will present the relation between JI music and some of the social/ethical ideas existing in the *Wandelweiser* collective. At the time of these personal first JI-discoveries, I became increasingly interested also in composed music dealing with a reduced musical material. I was undertaking a shift from

"solely" being an improviser towards working with both composing and interpretation of pieces. The Wandelweiser scene became influential in this respect. Wandelweiser is an international collective of composers and performers dedicated to a minimal or reduced aesthetic, favoring silence as well as a more open and simplistic approach to melody and harmony. The collective was founded by Antoine Beuger (1955 –) and Burkhard Schlothauer (1957 –) in the early 1990's, and notable Wandelweiser composer-performers include Jürg Frey (1953 –), Michael Pisaro-Liu (1961 –), Eva-Maria Houben (1955 –), as well as Beuger himself. Wandelweiser grew out of a common interest in John Cage's thoughts on silence, and besides a focus on silence as an element of musical significance, this scene also has a kinship to the *Fluxus*-scene originating in the 1960's, with its compositions based on *open form* and text scores often existing in the intersection between composition, poetry and performance art. Notable contributors to the Fluxus-scene also relevant to Wandelweiser more directly are Yoko Ono (1933 –), with her poetic text scores, and George Brecht (1926 – 2008), with text scores of a more absurd nature. Regarding Wandelwiser; silence, repetition, and fragments of melody and harmony that endorses the "beautiful" are all musical characteristics of the collective, combined with a focus on political, social and ethical dimensions. Beuger's music, for instance, focuses more on the social relations a piece of music can evoke than on sound itself[2]. A published source reflecting this is an interview with Beuger by Ian Power for the record label *Another Timbre*, where Beuger is describing the state of the performers in some of his pieces:

> [...]Then basically, the players, in all these pieces, they do the same thing. They play long, very quiet tones. Just long to very long tones. Whether you play Dedekind Duos or Florenski Septets or even Tunings for Twenty, this is what you do. There's nothing to practice, because individually everybody is engaging in the same activity. And they're going to find themselves in different kinds of constellations, if you like. While playing, they find out, hey, this is somehow different from, say, the other piece we played the other day when we had one person less or more. It's a very interesting experience, more like a social difference than a musical construction. (Another Timbre, n.d.)

[2] These insights stem from personal conversations with Beuger when we have been involved in a mutual musical project in 2019. I have his approval regarding these formulations about his work (Beuger, A., personal communication, March 2023).

Beuger's philosophy and approach to music is relevant to the kind of JI-music this research is about, even if this JI-music, quite contrary to what I understand as the core of Beuger's music, has the experiences of specific sonic qualities at its very core. A sensitive awareness to the real time enactment of sound is shared between the two musical practices, but that is also descriptive of an idealized state of music more generally. The core of the matter here, is that both these musical approaches encompass *non-hierarchical* social structures and engagement in something shared, where also the audience is included in an active engagement with the sound. Expressed in this way, this is neither descriptive of music generally, nor exclusive to these branches of music – it is rather a philosophical stance, and a step into the realm of *musicking*, to take Christopher Small's term (Small, 1998), where music is seen as an activity instead of an object, and where hierarchies between the different roles involved in a musical event are dissolving. A fusion of social and musical elements is evident in different ways in the music discussed in this research. In my piece *Six Moving Guitars* (discussed in section 4.4.), both social and spatial elements are parts of the musical idea in a more *Wandelweiserian* way, akin to the social dimensions in Beuger's music. The main connections of this sort is seen in chapter 5, where I argue that JI music entails a *shared mode of listening* both between the musicians, and between musicians and the audience. An aim for this research is to establish this idea both as a conclusive part of this research and as a foundation for possible further research. The motivation for bringing up Wandelweiser in particular is to contextualize and draw lines from the music of this research to other areas, sketching the bigger picture wherein these topics coexist and synergize.

2.3. The composer-performer-improviser

As my musical background and current praxis encompasses both composing, performing and improvising, I will here elaborate on the larger field characterized by this tripart approach. An example of this kind of music making that is especially relevant since I am based in Berlin, is the style of experimental music called *Echtzeitmusik.* Briefly described, Echtzeitmusik is a sub-genre of improvised music that originated in Berlin in the 1990's, with notable profiles such as Andrea Neumann, Robin Hayward, Axel Dörner and Burkhard Beins. Stylistic elements of this music include reduced sonic material, electro-acoustic sound, long durations of a unitary sonic material, etc. The personal music under scrutiny in this

thesis has a kinship both to the aesthetical and methodical aspects of Echtzeitmusik, and it is moving fluidly between composition, performance and improvisation as modes of musical creation.

2.4. Influences from *American experimentalism* and *Dhrupad*

Guided by the research questions, this research simultaneously gives a profile of *my* musical praxis and of the *broader field*, exemplified through this praxis, as I am part of a community of musicians working with **JI as a perceptual musical practice**, sharing aesthetic and methodical affinities. As stated in section 1.2., *minimalism, on-ear tuning, sustained sound* and *repetitive elements* are characteristics of the music in this research. Relating to the topics of community and context, the tradition of *American experimentalism* is especially influential on the music in question. Composers such as Alvin Lucier (1931 – 2021), Steve Reich (1936 –), James Tenney (1934 – 2006), John Cage (1912 – 1992), Morton Feldman (1926 – 1987) and Pauline Oliveros (1932 – 2016) are all North American composers and influential figures in this tradition. The *reduced* or *minimal* elements in these composers' work, such as repetition of rhythmic or melodic motifs and long lasting chords focusing on the timbral and perceptual qualities of harmony are all elements that are stylistically and aesthetically influential on the music this thesis revolves around. In the USA from the 1960s onwards, this scene fostered a new focus, also specifically on JI music. James Tenney and La Monte Young (1935 -) both stand out as two of the most important composers of JI music from this tradition and time, and they paved the way for the long-form JI music based on sustained notes that this research concentrates on.

Many of the composers investigating JI in this scene were inspired by Indian classical music and other traditions "untouched" by the *equal tempered system* (12-TET). La Monte Young is one of multiple American musicians of his generation that studied with the Indian classical singer Pandit Pran Nath (1918 - 1996). The primarily vocal-based Hindustani tradition called *Dhrupad* continues to be especially influential on the JI community, and also my music finds inspiration in this music, which is slower than other styles of Indian classical music, and where a solo vocalist sings melodies and long notes with a rich sonic palette fusing with the sustained *drone* of the string instrument called *tanpura.*

On a resource web page for Dhrupad created by musicologist and singer Ashish Sankrityayan, this quote in his article *The Fundamental Concepts of Dhrupad* (2006) illuminates the relation of Dhrupad to what in western terms is called *microtonality:*

> The dynamics of sound within a note makes it a fluid entity that is not fixed, but is a part of the infinite spectrum of notes created by overtones. [...] The background of a spectrum of overtones, to which a dhrupad singer sings, is provided by the drone instrument the tanpura, whose curved bridge with its shifting point of contact with the strings passing over it, embodies in its design the concept of a note as a fluid entity. (Sankrityayan, 2006)

As Sankrityayan points out there is a close sonic intertwinement between the overtone spectrum of the tanpura and of the sung notes. This *fusion* of overtones is one of the key elements of JI, which we will return to in the next chapter. A deeper delve into Dhrupad falls outside the scope of this research, however, in summary – Dhrupad is one of the major influences on the field of music discussed herein, and it comprises a branch of music where tuning and intonation is at the heart of the matter.

The present chapter is aimed at contextualizing this research. We have looked at my personal path with JI, and we have introduced *Wandelweiser*, *Echtzeitmusik, American experimentalism* and *Dhrupad* – all exemplifying artistic communities or traditions that the music in this research is either influenced by, situated in, or in communication with.

3 - Key elements of JI

This chapter explains the key elements integral to the certain approach to JI taken in this research. As these explanations are my own interpretations, formulations and thoughts on general or canonical knowledge in this field, they are partially belonging to the musical praxis (my own) that this research focuses on, *and* to its overarching context. The foundations of **explaining** how JI can work as an organizing principle, the relations between JI structure and perception, and how JI can be realized on musical instruments (including guitars), will be illuminated through corresponding key elements. Also, the arithmetical operations involved in the conceptualization of JI as rational numerical relations will be explained in tandem with

corresponding perceptual aspects. Generally, the explanations will be as straightforward as possible, and theory on the physics/acoustics of sound, the physiology, as well as the psychology of hearing – as much as they are the foundational sciences for these explanations, will not be covered in detail. Discussion of these sciences fall outside the main ambition and scope of this praxis based research, and my own insights into these sciences are generally limited to what can be useful for musical creation. The most impactful piece of literature in this respect, *On the Sensations of Tone* (originally published in 1885), by German physician Herman von Helmholtz (1821 – 1894), is a main resource in the field of tuning theory, and as the author remarks in the introduction to this book, explaining elements that have a *perceptual basis* is a hard task:

> Personal observation is better than the exactest description, especially when, as here, the subject of investigation is an analysis of sensations themselves, which are always extremely difficult to describe to those who have not experienced them (Helmholtz, 2007, p. 6)

On the background of this quote from Helmholtz, the present research imagines a reader with some, but not necessarily extensive experience with JI. I will stress that the explanatory elements of *key elements* presented in the following chapter can be rendered general JI knowledge and are hence not my own *findings* or *inventions*. However, their presentations are my own *formulations* and/or *interpretations* of this more general knowledge. External sources are provided when I see them suitable, and, at large, this is a hermeneutic project of *interpreting* both the hybrid tacit/propositional knowledge embedded in my praxis, and its *synthesis* with external sources. The reason for focusing quite extensively on a theoretical entry point to JI structure and perception, filtered both through my own understanding and through external sources, is shared between the aim of inserting the reader into key aspects of JI, *generally*, and *particularly* connected to the instance of JI praxis documented herein. Importantly also, the following chapter is an integral part of this research rather than an introduction to it. It is part of *systematizing the praxis* as presented in section 1.3. With this aim we will proceed, taking a brief look at comparative elements between temperament and JI, and their historical lines.

3.1. Differences between temperament and JI

In the following we will briefly look at just intonation and how it differs from 12-tone equal temperament. Illuminating these systems in light of each other is essential in the overarching field and history of tuning theory and praxis. The aim of this section, however, is to serve as an introduction to the key elements of JI specifically, by shedding light on a few comparative aspects between JI and 12-TET as two modes of organizing pitch, each with their structural, perceptual and functional differences.

Harmony can be described as the simultaneous sounding and blending of tonal sounds, or as The Concise Oxford Dictionary of Music introduces their entry on Harmony:

> The simultaneous sounding (i.e. combination) of notes, giving what is known as vertical mus., contrasted with horizontal mus. (counterpoint). (Kennedy & Kennedy, 2013)

We see that *harmony*, generally speaking, is coining the *simultaneity* of tones, rather than their temporal (melodic) succession. In the western classical tradition harmony is often classified into scales, chords, concepts of consonance and dissonance etc., and in functional relationships based on voice leading, dissonance resolving into consonance etc. In the context of western music, *just intonation* harmony, and the interrelations between rational numbers and musical tones that are integral to it, goes back at least to the famous Greek philosopher and mathematician Pythagoras (ca. 570 BC - 490 BC), and *Pythagorean* tuning, which will be discussed further in this thesis and in depth in section 4.2.2., originated in his theory and experimentation (Helmholtz, 2007, p. 278).

Before the standardization of 12-TET there were various approaches to musical tuning in the tradition of western composed music. Different non-equal temperaments such as various versions of *meantone temperament* were invented, closely approximating some of the just consonances, but on the cost of producing unavoidable, mistuned-sounding *wolf*-intervals arising from the pitch discrepancies between justly tuned thirds and fifths.
The standardization of 12-TET thwarted much of the musical usage and development of JI in western composed music, and new tonal approaches taking 12-TET as its point of departure

developed in the 20th century, such as the 12-tone technique invented by Arnold Schönberg and Olivier Messiaen's symmetrical scales.

One of the musical elements that is enabled by 12-TET is the way in which western classical music, as an emblematic music in 12-TET, is able to modulate extensively between different tonal centers, without encountering the tuning issues that a JI system meets because of its division of the octave into unequal parts. In an equally tempered tuning system such as 12-TET, every single note has the same tonal relations to the rest of the pitch set, and therefore the same tonal and functional potential or possibility space. Musicologist Christopher Small (1927-2011), as mentioned in section 2.2., remarks on the practical but arguably tonally limited 12-TET system:

> This total freedom of movement makes possible an infinite power of surprise, of interruption of the harmonic cycle, allowing composers to create tonal works of great power. But you cannot leave the system; there is no escape from it (Small, 1998, p. 128).

As Small argues, 12-TET provides the possibility to modulate freely between tonal centers, with all its potential for harmonic freedom exemplified in the enormous canon of music that 12-TET has fostered. However, as another musicologist and writer, Alain Daniélou, argues, this comes with the price of losing the clarity and *acoustic reality* of the simple harmonies of rational/just tuning. Daniélou (1907-1994) was also a historian and indologist, and in his analysis and comparison between the western tonal system, conditioned by 12-TET, and the modal systems of other non-western traditions, he is merciless in his description of the equal tempered system:

> […] the generalized use of equal temperament, which vastly oversimplifies musical structures, has led people to forget completely the most elementary acoustic realities and, by distorting all the intervals, has rendered the meaning of chords vague and unclear (Daniélou, 1995, p. 121).

This argumentation is built on the view that the just consonances are in concordance with the *acoustic realities*, as he coins it, of which the equal tempered consonances are mere

approximations. While Daniélou's views indicate a superiority of JI over 12-TET, the purpose of *this* thesis is rather to give an account of JI and its qualities on its own terms, than proving it superior in any sense. To this end, comparison with 12-TET is valuable because of its huge impact on harmony both today and historically.

While in principle retaining possibilities to realize functional harmony and rapid modulations, a just intonation system needs a far more detailed pitch set and theoretical navigation of it to accomplish such functional tasks. However, where 12-TET gives harmonic freedom of movement, JI, despite its limitations in these respects, provides deep, physical sonic qualities. Moreover, it is these sonic qualities, combined with the structural *limitations* as well as *possibilities* of JI, that comprise its musical *conditions* (as coined in section 1.2.) for composing, realizing and listening – all of which are foundational to this research.

3.2. Relations between descriptive and experiential concepts

Just intonation sounds have certain recognizable and rich sonic qualities when perceived by the human ear, sonic qualities that can be described through reference to theory, through other semantic or phenomenological means, or a combination. For instance when we say that a just intonation interval is *fused,* this can both refer to the theoretical concept of *tonal fusion*, namely the fusion of *harmonics* when two pitches form a just relationship, or the phenomenological quality of the sound "becoming one", i.e. the sound *appearing* fused. Importantly, the simultaneous unity and duality of meaning between theoretical and perceptual concepts is a general character of JI terms and concepts, because the things we hear call for a corresponding theoretical explanation, and the things we understand theoretically call for a corresponding experience of the sound as *perceived*. Consequently, the nature of the *relations* in research question 2 ultimately comprise a *codependency* between JI as structured and as perceived.

3.3. The harmonic series

The *harmonic series* (also called *overtone* series) is a physical phenomenon occurring in or from a single musical pitch, a so-called *fundamental pitch* (or just *fundamental*), and it can be

described as a sonic/vibrational manifestation of the whole numbers' (or *integers*') products (multiplications) of this pitch. It can be demonstrated with an example:

If a pitch frequency oscillates at 100 hertz (i.e. 100 periodic movements per second), its harmonic series will correspond to 100 hz (fundamental), 200 hz (second harmonic), 300 hz (third harmonic) etc, since these numbers are the fundamental pitch multiplied by 1, 2, 3, etc. String players will be familiar with these *natural harmonics* that sound when an activated string is touched lightly at one of the *nodes* dividing the strings in equal parts. Another way of expressing a pitch and its harmonic series is by *fractions,* or *ratios*[3] of the whole numbers, and the example above thus explained gives us: 1/1 (fundamental), 2/1 (second harmonic), 3/1 (third harmonic) etc. Conceptualizing JI intervals as ratios, i.e. numerical (or *rational*) relationships, gives us key insight into the canonical theory of just intonation, and as we shall see, it proves useful for navigating it musically.

We have seen here that by expressing tonal relationships as ratios of whole numbers, we are demonstrating their *harmonic* relations, i.e. how the tones would relate in an "imagined" or conceptual harmonic series whose fundamental frequency is expressed as '1'. Consequently, the harmonic series exists on two levels in JI theory and praxis – it is both a sonic phenomenon perceived as harmonics of tones, and a conceptual framework where JI ratios belong to an "imagined" harmonic series. When we *modulate* between multiple "imagined" harmonic series we can refer to them as *harmonic planes* (modulation will be covered at depth in sections 4.2.3. and 4.3.3.), corresponding with the concept of *keys* in standard music theory.

3.4. Interference and difference tones

With this account of the harmonic series and its rational tonal relations in mind, let us have a look at the different effects of both irrational and rational/just tuning in terms of *beating* or *interference* - whose *absence* creates the sonic quality characteristic of JI, as mentioned in the introduction (1.1). Beating or interference is the sonic result of the proportional *difference* between two simultaneously sounding frequencies forming an interval. Interestingly, it

[3] While the term *fraction* is most exact when referring to *numerical* relations, and *ratios* refer to *proportional* relations more broadly, for the sake of simplicity, I will in this thesis use the term *ratio* as an umbrella term covering the meanings of both *fraction* and *ratio.*

manifests either as a rhythmic pulsation or as a third discernible tone, depending on where the two generating pitches sit in the pitch continuum, and their proximity to each other. Let us make this clearer with an example:

A dyad consisting of the two pitches 200 hz and a 201 hz will have a difference of 1 hertz, giving one pulsation per second, and hence a sensation of pulse. Similarly, two pitches oscillating at 200 and 300 hz share a difference of 100 hz, and to the human ear this will sound like a musical pitch rather than a rhythmic pulsation - a so-called *difference tone.*

There are also middle grounds between the rhythmic and the tonal perceptions at play here, where a periodic or rhythmic quality appears as an integral part of the harmony, giving a certain "buzzing" quality that is characteristic of just intonation sounds. For instance when a 50 hz pitch is sounded together with a 40 hz pitch this gives a 10 hertz difference, which will be perceived somewhere "between" a rhythmic "roll" or "grain" and a tone.
As the relation of 50 hz and 40 hz is *proportionally* reducible to 5 and 4, we see that these two frequencies, together forming a 5/4 relationship (which is the *harmonic* major third*)*, have the fundamental '1' as their difference tone. Naturally, the difference of '1' will occur for all the ratios consisting of *adjacent numbers,* such as 5/4, 6/5, 13/12 etc., and this coinciding of their *difference tones* with the *fundamental* (of the conceptual or "imagined" harmonic series in which they are parts) make them sound particularly *rooted.*
The logical and factual opposite of a difference tone - namely the *sum* of two frequencies, called a *summation tone*, is another acoustic phenomena, but a more subtle one, and as this phenomenon has not had any bearing on the music that is the basis for this research, I will merely mention it here in passing.

Conceptualized either as individual tones or as a series of harmonic constituents, the tones making up a JI interval or chord consists of a segment of the very same harmonic series. And since the harmonic series is a sonic manifestation of a series of whole number relations, the differences, summations and harmonics generated in these tonal interactions will always constitute other whole number relations, molding into the totality of whole number relations rationally belonging to *one* harmonic series – hence sounding *as one*, *as fused*.

As we have seen, *beating/interference is the* sonic manifestation of the difference between pitches when the resulting frequency is low enough to be perceived as pulsation rather than as tone. Beating is particularly present in irrational harmony, due to the relationships "failing" to constitute a rational whole. However, also in rational relationships, the difference can manifest as pulsation. Moreover, because of the rational nature of the generating tones, these beatings/pulsations will not stick out, but *fuse* and comprise a facet of the sonic magnitude of the overall chord. This *rational* beating gives a "grainy" quality to the sound – experienced as a hybrid between rhythm and pitch and contributing to the vibrant physicality of JI perception[4].

The phenomena described hitherto are key elements we can use to describe the *tunability* of a musical interval or a chord. These phenomena, with an understanding of them comprising both practical and theoretical knowledge, serves as a foundation for learning, recognizing and producing the various intervals and chords, with their unique sonic qualities.

3.5. Harmonic fusion

Harmonic fusion is a sonic facet descriptive of the absence of *irrational* beating, characteristic of JI, and hence closely related to the topic of the preceding section (3.4.).

Contemporary composers/theoreticians Thomas Nicholson (1995 -) and Marc Sabat (1965 -) illuminate the concept of harmonic fusion in the following way:

> As the interval between two fundamental frequencies approaches a simple ratio, some of their respective partials come into alignment. This highlights unisons between partials by slowing down or eliminating the sensation of beating and, thereby, focusses the interval's characteristic sonority (Nicholson & Sabat, 2018, p. 2).

[4] *Rational beating* is closely related to the concept of *periodicity pitch* (or *missing fundamental*), and the scientific details and relations between difference tones, interference and *periodicity pitch* are beyond my theoretical JI knowledge. However their effect on my own *perception* of JI is evident, and as such they comprise a hermeneutic fusion of perception and theory, where the perceptual/experiential understanding takes over where a theoretical understanding is at its limits, with the two elements fusing together and completing each other.

As stated here, it is the *alignment* of harmonic series with different fundamental pitches that create or constitute harmonic fusion. When we express intervals as ratios, the numbers denote the relative speeds of the oscillations. With 5/4 as an example, this means that in every fourth cycle of the pitch denoted by 5 and in every fifth cycle of the pitch denoted by 4, the wave crests of the sound waves' coincide. The corresponding alignment of both the fundamental frequencies (5 and 4 respectively) and their corresponding *harmonic series* results in harmonic *fusion*, which, as described earlier, has a vigorous sonic character of clarity and stability. The way that the harmonics align can be shown with the following table:

harmonic	fund / 1st	2nd	3rd	4th	5th	6th
6 first harm. of 5	5	10	15	20	25	30
6 first harm. of 4	4	8	12	16	20	24

Each of the vertical relations shown here can be simplified as 5/4, since the distance of the 5/4 ratio will remain between the harmonics of similar numbers, generated by 5 and 4 respectively. However, different rational intervals arise from the different harmonics of each series. For instance, the fourth harmonic of 4 (4x4) and the third harmonic of 5 (5x3) gives us the interval 16/15. Furthermore, the 5th harmonic of 4 (5x4) coincides with the 4th harmonic of 5 (4x5). This product, 20, is what is called the *least common partial* of 5 and 4*,* and this pitch, shared between their two harmonic series, will be amplified or accentuated in the overall sound.

To avoid confusion of terms, let us specify the difference in usage between *fundamental* and *generative tone.* In the example above, the tones denoted by the harmonic numbers 5 and 4 can be described as *fundamentals* when we look at them one by one and describe their respective harmonic series, since the fundamental is a tone that is not itself an harmonic, but a tone which *generates* a harmonic series. When we look at 5 and 4 combining in the JI interval 5/4, they are, as described earlier, conceptualized as *constituents* of a harmonic series and not as individual fundamental tones. However, since these tones are also producing their own respective harmonic series, we can call them *generative tones* when we see both these "roles"

at once and conceptualize them both as parts of the same harmonic series *and* as fundamental tones that generate their own respective harmonic series.

Let us sum up the three phenomena we have discussed so far. When two tones constituting an interval are tuned as a rational relationship, the *interference/beating* stops because the two tones and their respective harmonic series manifest a collection of rationally relating numbers, and the resulting harmonic alignments of these rational relations cause *harmonic fusion*. We can also explain this with the entry point of the words *fusion* and *difference* detached from their technical meanings in JI context, with some philosophical and poetic consequences. Interference *is* a sonic manifestation of the *difference* between two tones, and when this difference becomes rationally related to the two generating tones, which can only happen by these two tones relating rationally to *each other*, all three tones (including the difference tone) align in one series of rational relations, and in this new identity of the tones as aligned into a unity, the feeling of difference evaporates as the individual tones gradually fuse into *unity*, unite in *fusion*. From this we can make the philosophical generalization that the difference between things is altered when these things come to interrelate in a whole – their identities as individual parts transform into the appearing whole in which they come to constitute.

The phenomena we have described hitherto are examples of interconnections between structural and perceptual aspects of JI - namely the sonic and theoretical interconnections of *harmonic series, interference* and *harmonic fusion.*

3.6. *Tunability* as organizing principle

With close reference to the terms and phenomena we have discussed thus far, we will have a closer look at the concept of *tunability*. Basically, the tunability of a JI sound (i.e. chord or interval) is its perceptual *identity.* It comprises a conglomerate of properties that makes JI sounds recognizable and repeatable. While tunability applies to any amount of notes combined, we will for the time being focus on the tunability of combinations of two notes at a time, since these *dyads* or *intervals* comprise harmony in its most fundamental form. While tunability can be analyzed systematically through empirical studies of lists of JI intervals, e.g. as documented in the collaborative research by Robin Hayward and Marc Sabat (Hayward &

Sabat, 2006), in the present research tunability refers to the general quality of a JI interval or chord that enables a performer, to varying degrees, to tune it by ear. One can argue that not only *just* intervals, but any interval in the pitch continuum, regardless of intonation, can be recognized, learned and repeated. However, there are certain properties that only just intonation intervals and chords have, properties that make them perceptually categorizable as 'just' in the first place. Moreover, if we could not *discern* or in any way hear these properties, JI would have no sonic or musical significance.

In my own experience, the process of tuning just harmony by ear starts with knowing approximately what kind of interval I am looking for. Since I have training in a western music tradition, I am used to categorizing musical intervals as *unison, minor/major second, minor/major third* etc. And with experience from ear training involving identifying and reproducing the different intervals in the standard (western) 12-TET-system, the basic skill of recognizing musical intervals is already developed. From this foundation I direct my focus on the micro-differences in intonation and how they affect the sound of an interval. To return to the 5/4 interval – since it consists of very small numbers, its sonic "gravitational force" is salient - there is a striking *feeling* of when it is in tune and when it is not, and my hearing almost instinctively wants a major third to be tuned as 5/4.

In my opinion, there is a beauty in the correlation between the physical/mathematical analysis and the corresponding sound. The "tidiness" or simplicity of how the sound waves relate in small/whole number relationships, and how this can be manifested in sound which we can perceive and describe as *stable, clear, full, transparent* etc, is something I find compelling. More substantially, the *kinds* of correlations, in which JI perception/theory is an instance, where we have a feeling of *experiencing* the relation between the analysis and the thing that is subject to this analysis, is a source of enchantment. Note that this is described as a *correlation* and not a *reduction* – I do not here deem JI perception or, *a fortiori*, any perception, as conceptually *reducible* to an associated theory. However, when theories and perceptual phenomena happen to correlate conceptually, it is rewarding and helps us build a holistic picture of the object under scrutiny.

3.7. Calculating ratios

Let us briefly look at how adding or "stacking" intervals, as well as subtracting one interval from another to find the intervallic difference between them, is carried out through simple multiplications or divisions between the intervallic ratios in question.

The total scope of the interval consisting of two "stacked" intervals, e.g. two (3/2) fifths, is the same as the *product* of their ratios:

3/2 x 3/2 = 9/4

The intervallic difference between two intervals, e.g. the fifth (3/2) and the fourth (4/3), is the same as the *quotient* of the two intervals – i.e. the larger interval, 3/2 divided by the smaller, 4/3. This operation is the same as *multiplying* 3/2 with the *inverse ratio* of 4/3, namely 3/4.

3/2 x 3/4 = 9/8

We see that the difference, i.e. the interval between 3/2 and 4/3 is the *Pythagorean* whole tone 9/8.

3.8. Primes and compound numbers

We have seen that JI can be described as two or more oscillations of sound waves relating to each other as whole number ratios. Described as such, the *compound* numbers and the *prime* numbers have different *sonic* qualities corresponding with their different *arithmetical* properties – revealing another relation between perceptual and structural elements of JI. Compound numbers and their intervallic sound-manifestations can be broken down into products (i.e. "stackings") of simpler numbers/intervals, while the prime numbers are not generated from products of simpler numbers since they are only divisible by 1 and themselves. Consequently, when a new *prime* is introduced, its corresponding new *intervals*/*harmonic sounds* are introduced as well.

Harmonic analysis in JI-terms often involves specifying the selection of prime numbers at play, or the highest prime number involved in generating intervals. The former is called *prime space*, while the latter is called *prime limit*. E.g. in *13-limit* harmony, none of the occurring harmonic relations can be simplified into products of any prime exceeding 13. To give further examples of the structural properties of *prime limits*, the connection between the following intervals and their prime limits are shown by the elemental arithmetic operation called *prime factorization,* i.e. breaking the harmonic numbers of the intervals down into the products of the prime numbers involved in generating them:

21/16 is 7-limit, because 21 = 3 x 7 and 16 = 2 x 2 x 2 x 2. Hence, 7 is the highest prime involved.

39/32 is 13-limit, because 39 = 3 x 13 and 32 = 2 x 2 x 2 x 2 x 2. Hence, 13 is the highest prime involved.

81/80 is 5-limit, because 81 = 3 x 3 x 3 x 3 and 80 = 2 x 2 x 2 x 2 x 5. Hence, 5 is the highest prime involved.

To sum up, intervals expressible as compound numbers are products of simpler numbers while the intervals expressible as prime numbers bring in a new interval class and new sonic properties with their own perceptual signatures. Hence, this is another example of a connection between structure and perception in JI, and another partial answer to research question 2.

3.9. Commas

A *comma* is a small just intonation interval comprising the intervallic difference between two intervals of different prime limits, whose intervallic sizes are close to coinciding.
The most elemental one is the *syntonic* comma, 81/80, already exemplified in our prime factorization above, and it is the intervallic difference between a 3-limit (or *Pythagorean*) and a 5-limit (so-called *Ptolemaic* or *harmonic)* major third. Starting with the Pythagorean, let us have a look at how we reach the two mentioned intonations of the major third, to distill the comma in comparing them. We reach the major third of a tone by stacking four (3/2) fifths

and *reducing* the octaves, i.e. expressing the interval as it appears inside the scope of one octave. First, we find the harmonic number of these four stacked fifths, which entails multiplying the numerator (of 3/2) with itself three times (i.e. multiplying the fundamental, 1 with 3 *four* times):

(1 x) 3 x 3 x 3 x 3 = 81

Then, for the newly found 81 to express the top note of a major third in relation to a root note stemming from our fundamental (1), we need to find the closest octave transposition of the fundamental *below* 81, which amounts to doubling the fundamental (1) six times:

(1 x) 2 x 2 x 2 x 2 x 2 x 2 = 64

From this we see that the Pythagorean major third, expressed as a ratio, is 81/64.

As we know, the 5-limit major third has the much simpler ratio 5/4. However, to see the proportional difference between 5/4 and 81/64, they need a shared denominator, and as we cannot simplify 81/64, we have to transpose 5/4 “upwards” to align their denominators. To achieve this we have to multiply (both the numerator and the denominator of) 5/4 by 16, since 4 x 16 = 64. This amounts to transposing the interval up four octaves, since 64 = 4 x 2 x 2 x 2 x 2, i.e. four doublings of our original denominator, 4. As the numerator, 5, multiplied with 16 gives us 80, we see that the intervallic ratio of 5/4, when transposed upwards 4 octaves, arrives at 80/64.

Since the Pythagorean and the 5-limit major thirds thus expressed share the root note and denominator, 64, we can infer that the interval *between* the two intervals is 81/80, i.e. the syntonic comma.

To finish this section about commas, let us look at the syntonic comma and two other commas both through their compound products and prime factorization:

Syntonic comma, 81/80:

9x9	or	3 x 3 x 3 x 3	(3-limit)	=	81
8x10	or	2 x 2 x 2 x 2 x 5	(5-limit)	=	80

Septimal comma, 64/63:

8x8	or	2 x 2 x 2	(2-limit)	=	64
7x9	or	3 x 3 x 7	(7-limit)	=	63

Septimal quarter tone, 36/35

6x6	or	2 x 2 x 3 x 3	(3-limit)	=	36
5x7	-		(7-limit)	=	35

In relation to the research questions – through the ways in which commas can be used as shifting points between prime limits and their almost coinciding intervals, and thus create timbral changes in the music, they can (1) be used in organizing JI composition, (2) exemplify structural and perceptual interconnections, (3) serve as a theoretical tool guiding composition and realization of JI on the guitar, *especially* when working with techniques where *glissandi*/gradual transitions between notes, and/or small intervallic changes are parts of the logic of the technique in question, examples of which we will see in the case studies (Chapter 4).

3.10. Some remarks on notation and orientation in JI

There are many notational practices in different JI communities, but the one I have learnt to implement in my practice is *The Helmholtz-Ellis JI Pitch Notation* (HEJI), invented by Marc Sabat and Wolfgang von Schweinitz (Nicholson & Sabat, 2020). This system adapts standard staff notation, adding specialized accidentals to specify the JI pitches, while excluding equal temperament altogether. In HEJI, a notehead lacking an accidental is hence not denoting a 12-TET note, but a Pythagorean one. The Pythagorean system, both comprising the *lowest* prime-limit and the one most closely resembling 12-TET, is the basis from which the

higher-prime notes can relate as deviations. HEJI-notes are often accompanied by *cent*[5]-deviations connected to each note, denoting its difference to the closest 12-TET note.

3.11. Naming and definitions of JI

As we have seen so far, the JI field has an abounding terminology, but there are also various ways of naming and defining the core concept of JI itself. In particular contexts, *just intonation* simply means 5-limit tuning, referring to the most consonant way of tuning "normal"/western harmony. Relating to this practice, inclusion of prime-limits beyond 5 is called *extended just intonation*. However, as it is also commonplace to use *just intonation* (*JI*) as an umbrella term including higher prime limits, this is how I use the term in this research. Another practice is to swap the word *just* for *rational,* which, in addressing the *rational* nature of numerical relations pertaining to JI, a topic we have already introduced earlier in this chapter, gives us the term *rational intonation* – hence also avoiding the normative connotations of the word *just.* However, as *just intonation* is the more common term, it is favored over *rational intonation* in this text. Another term is *harmonic space,* invented by James Tenney, describing how tonal relations are conceptualized in a geometric multi-dimensional space, wherein each prime limit creates its own trajectory or dimension. In coining this term, Tenney was building on the foundation of harmonic *lattices*, as employed by composer Ben Johnston (1926 – 2019) in explaining JI relations (Tenney, 2019, p. 296 – 298). While *harmonic space* is a concept within or closely related to just intonation, descriptive of an overarching framework of JI harmony, *just intonation* addresses the *act* of intonating, i.e. the placing of one or more tones somewhere in a pitch continuum, harmonically and/or melodically relating to other discrete tones.

3.12. Preliminary conclusions and summing up

So far we have looked at key theoretical aspects of JI, and of sound phenomena connected to pitch and pitch relations generally. We have seen how intervals and chords can be expressed as rational numerical relationships called *ratios*, and how we can stack/multiply and subtract/divide ratios with simple mathematical means.

[5] Invented by Alexander J. Ellis (1814 – 1890) and discussed in his English translation of Helmholtz' *On the Sensations of Tone* (Helmholtz, 2007, p. 41), a *cent* is a unit in the measurement that divides a 12-tone equal tempered semitone into 100 equal parts, i.e. *cents*.

We have also seen the ways in which the two theoretical frameworks of JI and standard musical theory can work in tandem to yield a unitary foundational knowledge from which the experience of JI tuning can proceed and be conceptualized. From what we have discussed thus far, important aspects of the perceptual and structural relations of JI are already illuminated, and we have seen ways in which JI perception and structure are interconnected. These insights will be embedded into the following discussions of the case studies, which will also spell out these matters further, as well as exemplifying both JI as an organizing principle in composition and JI approaches to the guitar.

4 - Case studies

In the following case studies, and guided by the research questions, we will see how the key concepts of JI are employed in my own musical practice through analysis of four original compositions, and in comparison with pieces by Marc Sabat and Catherine Lamb.

4.1. Case studies (I) – *Svevning*

Svevning is a longform solo piece for a humming guitarist. It is the first of my pieces employing real-time retuning of strings to just ratios. In Norwegian, *svevning* means both *levitating*, and *interference* (in the sonic/acoustical meaning of the word), both of which are descriptive of the music in different ways. This piece went through many developmental stages before finalizing as the approximately 80-minute long version in 2020[6]. The initial idea for the piece was combining plucking and real time tuning of guitar strings, played open or with their natural harmonics, to create a slowly developing harmonic structure, changing gradually note by note. *Svevning* also introduced the implementation of my own voice into my solo work, with hummed notes blending with the timbre of the guitar, occasionally and freely joining in at the points in time where the process of tuning has settled and entered into the *perceived* just sound. The process of JI *tuning*, whereof *Svevning* gives an example, is always a perceptual play involving *listening*, to gather information about the sound, and *adjusting/tuning* correspondingly until the "tuned state" of the harmony one is engaged in realizing, or its closest possible approximation, is achieved. A natural question regarding this kind of music based on the process of tuning is: are there other musical elements present in

[6] *Svevning* was subsequently recorded and released by INSUB records in 2021 (Rasten, 2021)

this music, and how do they relate to the JI/tuning elements? An answer is that this music, at the present exemplified by *Svevning*, is composed in a way where the tuning, as a *state* and as a *process*, is the main musical focus, and where, to varying degrees, other musical parameters such as pace, form, dynamic and timing are always conditioned by (the process of) tuning. This means that an enabling of good possibilities of realizing the tuning conditions the possibility space of rhythm, pace, dynamics, and other parameters. As an aesthetical and practical consequence of this, the music in question generally *favors sustained sound and/or repetitive elements,* as stated in section 1.2. In the following sections we will look at *Svevning* through the lens of the research questions and through Borgdorff's categories process, object and context, before comparing the piece with Lamb's guitar piece *Point/Wave*.

4.1.1. Tuning and retuning in *Svevning*

As described in section 1.1., Catherine Lamb's piece *Point/Wave* introduced me to just tunings on guitar, and with inspiration from that piece I created my own "standard" tuning, which we can call the *D-tuning*, since D is its fundamental and tonal reference point.
With the D-tuning as a starting-point, I explored real-time *re*tuning of individual strings as a means for creating tonal change, eventually leading to the composing of this piece.
The D-tuning is based on ratios from a single harmonic series where D 146,66 hz works as a main reference point, and where the entire tuning is a segment of an harmonic series with a fundamental frequency of 18,33 hz – i.e. D three octaves lower than the reference point D.
The following table denotes the string numbers, frequencies, cent deviations, ratios to the two different reference Ds, and prime limits comprising the *D-tuning*:

String	Frequency in hz	Note with cent deviation from 12-TET	Ratio to reference D (146,66 hz)	Ratio to common fundamental D (18,33 hz)	Prime limit
1	275	C# -14	15/8	15/1	5
2	256,66	C -33	7/4	14/1	7
3	165	E +2	9/8	9/1	3 / Pythagorean
4	146,66	D -2	1/1	8/1	1
5	110	A +/-0	3/4	6/1	3 / Pythagorean
6	91,66	F# -16	5/8	5/1	5

Notes working as *reference points* are key parts of JI conceptualization. The two Ds here work as reference points in two different ways – the higher D is a tuned string on the guitar, and is hence a reference point available both practically and sonically. The lower D has more of a conceptual referential value, i.e comprising the fundamental of the unitary harmonic series encapsulating all six notes. Additionally, the tuning as a whole is relating to A 440 hz as an overarching reference point, since this frequency (as well as any of its octaves, such as 110 hz, appearing in the tuning), is not deviating from the A 440 hz used as a standard reference also in 12-TET (hence, 'A+/- 0', in the table). As mentioned, the column "Ratio to common fundamental…" shows the pitches of the open strings described as harmonic relations to their common fundamental (the *denominator* of each ratio), and since the fundamental/denominator is a shared point of reference between all these ratios, we can ignore it for a moment to see the strings' rational relations to *each other*:

5 / 6 / 8 / 9 / 14 / 15

All of these are 3- and 5-limit relations except one, the 7/4 or *septimal* C. Being acquainted to 12-TET and western classical harmony, the 3- and 5-limit relations do not really come across as microtonal, since they constitute "normal" intervals, e.g. as they appear in minor-, major- and sus-chords – tuned in their arguably most consonant way. The *septimal* (7-limit) C, on the other hand, comes across as more microtonal and unfamiliar in a standardized (western) way of hearing harmony, and as such it is often associated with a "bluesy" sound.

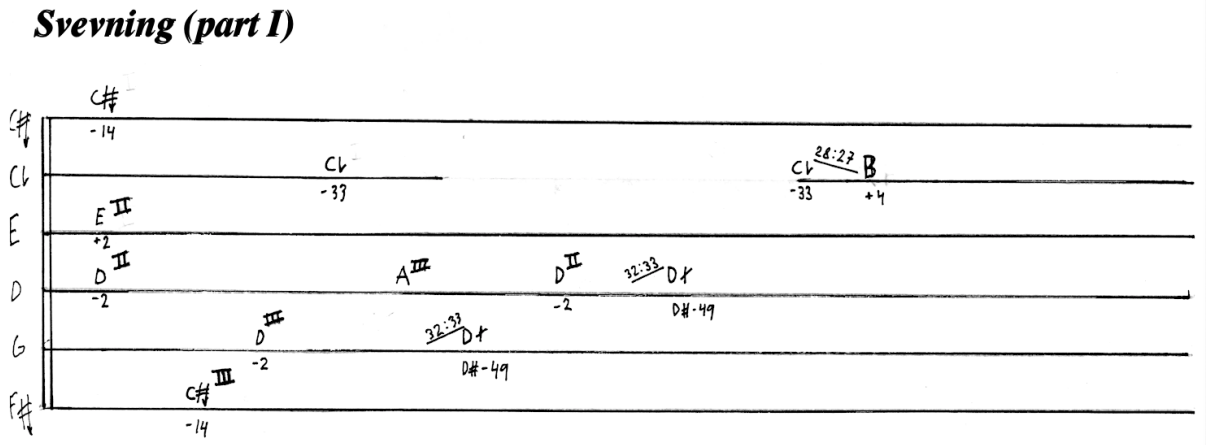
4.1.2. Just intonation as an organizing principle in *Svevning*

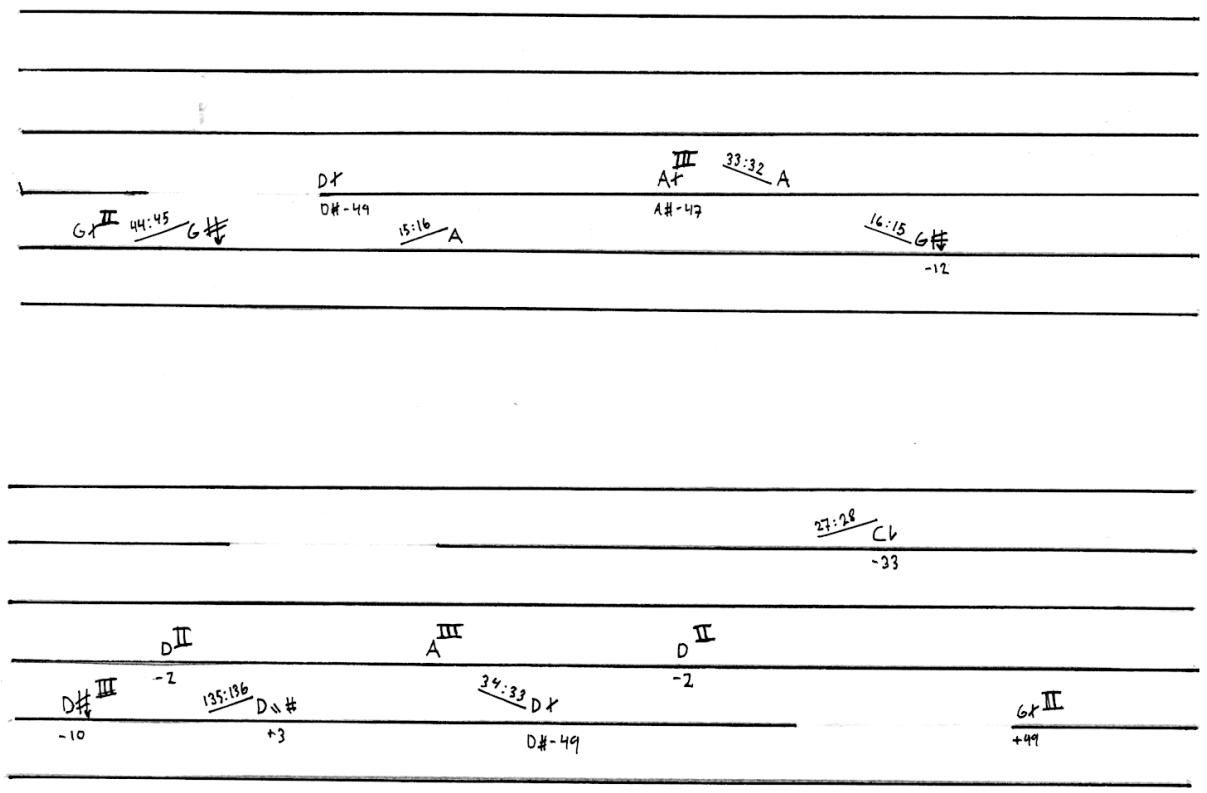
As I work with improvisation and composition as a joint venture, an overarching question for me regarding composition involving scores is: *which elements are necessary parts of the composition/score, and which elements can remain open or flexible?* For myself, mainly being the performer of my own pieces but also occasionally having my pieces played by or with others, this is a core question in my approach to composition. In the context of this research it is particularly relevant to research question 1 and 3 concerning the ways in which I use JI as an organizing principle in composition, and in approaching the guitar. *Svevning* is an example of how improvisation can be implemented into composition. The composition as

such is the harmonic succession and hence also the specific strings played, either the "undisturbed", open string, or with activated harmonic nodes/natural harmonics.
The ways in which the piece is realized – how strings are plucked (technically as well as rhythmically), when the voice enters, how to relate to tempo and dynamics etc., are all up to the performer's personal approach to the material, and as such these aspects of realization exist between the spontaneity of improvisation and adhering to personal customs or *tacit* rules. In this sense, my compositions are *just intonation frameworks*, where the harmony is fixed, but where improvisation, habits of realization and tacit rules all govern the remaining musical elements. In this approach, JI is used as the main organizing principle of the musical composition, conditioned by the instrumentation (guitar and voice), and the possibilities for improvising or creating personalized playing techniques within the harmonic framework. Consequently, *Svevning*, even as a finished piece or *object*, is still in *process*, and iterations vary between different *contexts*, relating to Borgdorff's usage of these terms.

With this renewed view of *Svevning* as a *JI framework*, let us look at the layout and logic of the score. The score has tablature staves, showing each of the six strings horizontally on the page, denoting each note with the combination of note name and accidental in the HEJI-system, cent deviations from 12-TET, and the rational intervallic movement from one note to the next.

The following three tablature staves comprise the first page of the score for *Svevning* (Rasten, 2021):





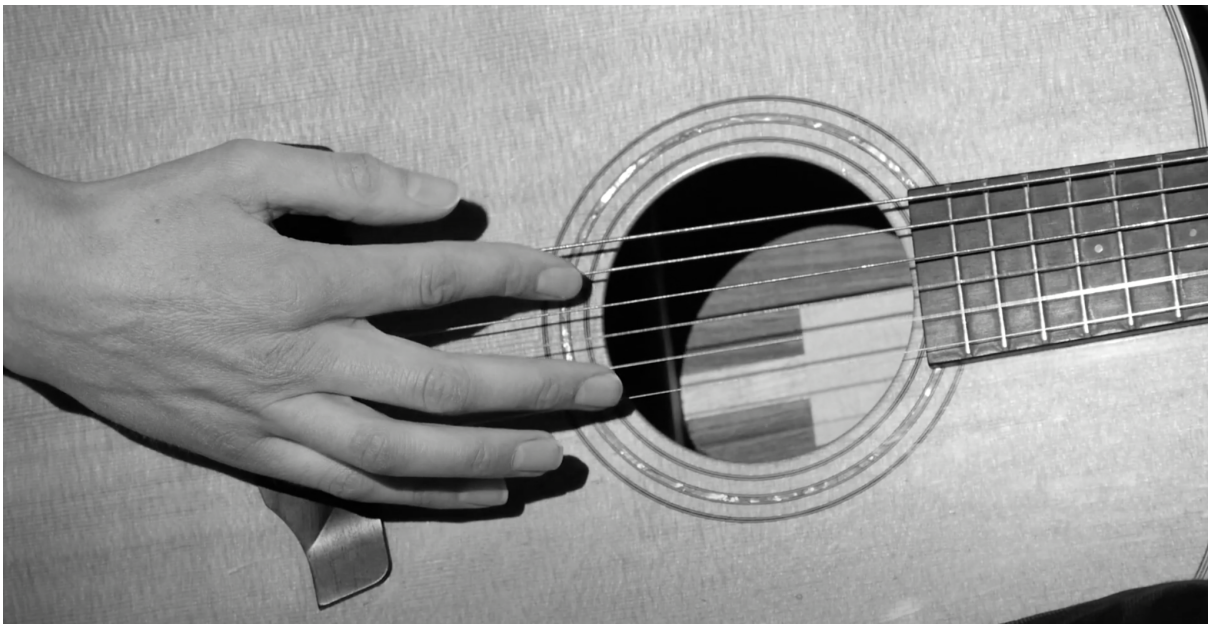
Fredrik Rasten (2021)

Melodic (horizontal) relations are normally connected with a *colon* instead of a *slash* in the language of JI, a practice used in the score. For instance, in the first retuning, 32:33 denotes the rational distance between the two notes involved. Each retuning entails either a change within one *harmonic plane* (as introduced in section 3.3.) or it entails a change to another harmonic plane, which is called a *modulation* – a topic we will focus more on in the next two case studies (4.2 and 4.3.). As we can see from this excerpt, the tablature lines have occasional gaps in them, thereby showing which strings are in use and which strings are not at any given stage in the unfolding of the piece.

4.1.3. Guitar technique

Relating to research question 3, I want to address some of the guitar-technical aspects of realizing the piece. In *Svevning* I utilize a specific self-made right hand technique that has developed and been in use in my guitar praxis for many years. The technique is a version of "rest stroke" / *apoyando*, but differing from this in that the fingers lay horizontally on the string, activating it with the "flesh" of the finger and with a huge contact point between the

string and the finger, producing full-sounding, rounded tones. Since the fingers “fall” onto the adjacent string after plucking, the performer can readily and quickly pluck this adjacent string after the initial pluck – providing a huge degree of accuracy, quite similar to “sweep picking” which is a widespread plectrum-based guitar-technique in jazz, rock etc.



A picture showing the technique and hand position used in *Svevning*. Video still from video by Uli Decker from a concert at Labor Sonor, Berlin, March 2019. At this developmental stage of the piece it was titled *Limn* (Rasten, March 26, 2019)

Another technique that I use extensively, both in *Svevning* and other settings, is a (left hand) dampening of the openly plucked strings by the nut, near the headstock of the guitar.
This also contributes to a rounded tone quality and makes the *openly* plucked strings sound more similar to the strings plucked with *natural harmonics*.

These, and other techniques used in my guitar practice belong to a personalized and idiosyncratic instrumental approach, which is emblematic of the *composer-performer-improviser* in the experimental field of music. In conceptualizing technique, I agree with Magda Mayas (that I mentioned in the introduction), in her characterization of technique in her practice:

> [...]I argue for and offer a detailed and intimate approach to technique and material, which opposes the notion that (extended) technique can be generalizable, reproducible, or transferrable. Likewise, I feel that the term "extended technique" is somewhat reductive, because it divides instrumental approaches into traditional versus extended, or non-traditional, categories. This is to disregard the complex historical and philosophical contexts of instrumental approaches[...] (Mayas, 2019, p. 28).

As I interpret Mayas' take on ("extended") techniques as *detailed and intimate* as opposed to *generalizable* etc., this is in accordance with how I describe them as personalized and idiosyncratic. These descriptions encapsulates technique as specific both to performer and to situation, instead of the tendency (according to Mayas) of rendering it *generalizable, reproducible, or transferable*.

4.1.4. The use of voice in *Svevning*

Voice is a recurring element in my JI praxis, and this is connected to the perceptual immediacy of singing. Through singing, the feeling of producing a tone and its immediate vibratory qualities are connected. In *Svevning*, the initial idea of implementing voice was the effort of making it, ideally, audibly inseparable from the guitar timbre. To this end, the voice is approached with a rounded tone, resembling a *sine wave* – blending into the timbre of the rounded guitar tones,"thickening" the overall timbre and "masking" the decay of the strings. In my opinion, JI accentuates the *physicality* of sound to the extent that it feels tactile or substance-like. And ultimately, when I implement singing in combination with guitar, this is a way of immersing myself in the sonic physicality and a connected intention of *embodying* the sound. Altogether, these are aspects belonging to JI as a *perceptual* praxis.

4.1.5. JI tuning as process in *Svevning*

In the introduction of the research questions (1.2.), we looked at the interconnectedness of the research questions through a venn-diagram (fig. 1), and since *Svevning* is an example of how I use just intonation as a compositional *organizing principle* and how this organization can be combined with personalized guitar techniques, this connection corresponds to the intersection of research question 1 and 3. In this section we will see how the 2nd research question relates to the 1st and 3rd in *Svevning*, the intersection of all three research questions.

In this piece, the individual tuning pegs for each string are given a new role beyond their standard function of *pre*tuning to a particular guitar tuning before the music starts. In *Svevning* they are used in the musical unfolding itself, changing the overall harmony by slowly tuning the strings to new tunable relationships, and in every *tuned state* there is a possibility for the voice to subtly enter the sound and blend with one of the already sounding notes. Importantly, we see that tuning is a *process* from one (tuneable) chord to another. As already established in the second chapter, tunability is conditioned by the particular sonic qualities that characterize just tonal relationships. Most *perceptually* notable in this respect is the slowing down of the beating frequency/interference as an interval "falls into tune" - it *stabilizes* when the interval forms a just relationship with the overall harmony. Each retuning is performed slowly, creating a gradual "departure from", and "arrival at" the two respective tones involved. In this way, the *process* of retuning comes into the spotlight, as both the performer and the listener hears the beatings occuring in an untuned state and its gradual slowing down until the interval reaches its just and stable state. The *transparency* of this real-time process of shaping the harmonic material is simultaneously an aesthetical, a human and a social quality of this kind of music making – and this is a topic we will cover more thoroughly in chapter 5. Tuning as a *process* demonstrates the manner in which the vibrations of harmonic relations generate both stability (non-beating) and rhythm (rational and irrational beating) and how intonation of pitch relations governs the interplay between these two *vibratory states* manifested in/as tonal interaction. Since the *process* of JI tuning is integral to the music it appears in, consequently also the untuned states and their interferences are to some extent natural parts of the music. As such, encompassing both tuned and untuned states as parts of the process of tuning can be compared with suspension and resolution in more standard functional approaches to harmony. Where the latter involves the resolution of what is understood as a dissonance into what is understood as a consonance, the former moves between two tuned states *via* an unstable (beating) sound. In both instances a more complex or "restless" sound transforms into a simpler or "calmer" one, where the latter evidently appears with certain qualities *in contrast* to the former. The perceived contrast between the two states hence clarifies their perceptual and affectual identities – as *different* from each other. Since the musical traits discussed in this thesis generally endorse sustained or repeated harmonic material and hence also instantiate a certain *monotony*, a conscious stance to

contrast, even very subtle application of it, can enrich the music. Moreover, when exposed to sustained harmonic sound, our perception changes and we *become* more aware of the details and micro-contrasts that are there to discover. This entry-point to *contrast* belongs to the *mode of listening* to JI, or *listening attitudes* more generally, which is something we will return to in chapter 5..

Having looked at the dynamics of tuning in the example of *Svevning*, we see again how *relations between structure and perception of JI* conditions the possibility space of the music, and how the relations in question are more exactly described as *connections*, since they are mutually dependent on each other. Whereas these connections can be shown through many instances, such as recognizing and fine-tuning a certain interval in relation to *prime-limit*, guided by *intervallic identity* belonging to standard musical theory, or other conceptualizations of JI structure, the main overarching connection wherein they all belong as is *tunability*, i.e. knowing, recognizing and fine tuning JI sounds. Tunability is perception (as sound) and structure (as theory/conceptualization of sound) synthesizing into *experience* with sound. The interconnectedness of all three research questions in relation to *Svevning* can be summed up as such: real-time tuning, as exemplified in *Svevning*, is a way of realizing JI on guitar, which is enabled through the combination of the structural and perceptual connections constituting *tunability*, and the way that the conditions inherent to the guitar itself have implications on the possibilities of JI to serve as a way of *organizing* harmonic and melodic material.

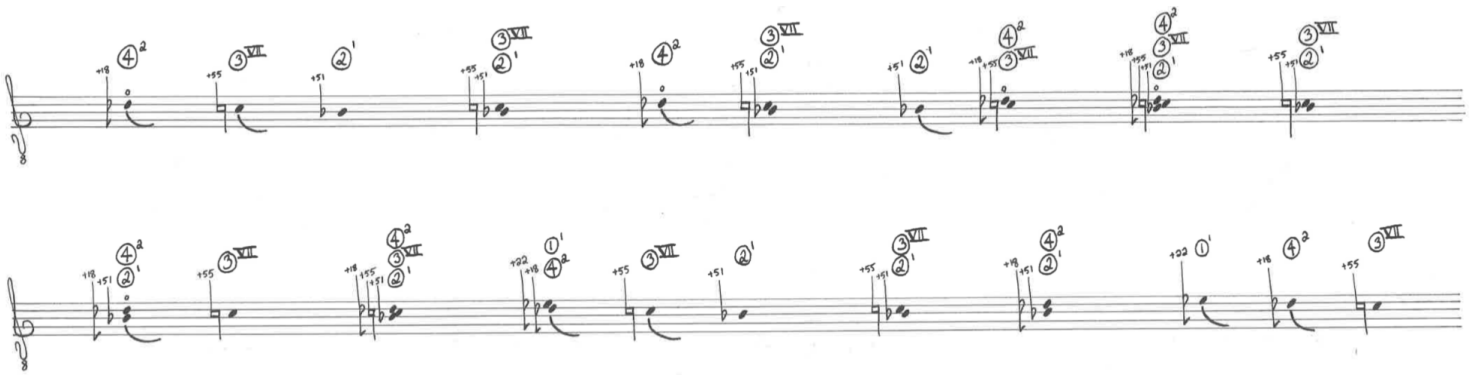
4.1.6. Comparison between *Svevning* and Catherine Lamb's *Point/Wave*

Catherine Lamb's guitar piece *Point/Wave*[7] has been formative for me in approaching JI as a guitarist, and the sound world that this piece opened has influenced *Svevning* as well. We will now compare the two pieces – their tuning systems, layouts of the scores, each piece's relation to open versus fixed elements, as well as how and to which extent both pieces demonstrate JI as an organizing principle. As a start, we observe that both pieces are slowly unfolding, without a typical linear form or narrative. They are also both making extensive use of the first four natural harmonics of the open strings, creating slow successions of dense

[7] Audio released on Another Timbre (at142) in 2019 (Lamb, 2019)

chords and dyads in the middle register of the guitar. The tuning in *Point/Wave* is 31-limit, meaning that the highest prime occuring in the tonal gamut is 31. Not every prime up to 31 is present, but a selection consisting of (2), 3, 7, 11 and 31, thereby omitting tonal material generated from the primes between 11 and 31, namely 13, 17, 19, 23 and 29.
On the contrary, the tuning for *Svevning* is 17-limit and includes all the primes in that scope: (2), 3, 5, 7, 11, 13 and 17. Both tunings have a focus on the *Pythagorean* structures including 4/3 fourths, 3/2 fifths and 9/8 major seconds, the *septimal*/7-limit-, and the 11-limit intervals. The 11th harmonic, manifested as an 11/8 ratio (also called the *natural tritone*), is a quarter tone narrower than the 12-TET tritone, and is heard e.g. in Norwegian folk music, where the harmonic series is a harmonically generative resource. Whereas Lamb's piece excludes the 5-limit, with its highly consonant thirds, sixths and major seventh, I employ these tonalities in *Svevning.* In general, as much as adding primes to a tonal gamut *gives* a certain tonal flavor, *excluding* certain primes is at least as effective. As a general observation we can say that the fewer different things added to a totality, the more focus is given to the things included. However, despite omitting *prime-exclusion* within its prime-limit, this value also applies to *Svevning*. Even if the whole scope of primes between 2 and 17 is included, they are distributed in various combinations over the totality of 80 minutes – enabled by the element of real-time tuning and its possibilities to radically change the harmony throughout the piece. In sum, where *Svevning* focuses on a continusouly metamorphic development through real-time tuning including the entire scope of primes up to 17, *Point/Wave* utilizes a fixed tuning of selected primes to venture into a deep exploration of their latent sonorities, melodies and chords.

There are also both similarities and differences in the ways that the two pieces are notated. As shown in section 4.1.2., *Svevning* is notated in a tablature form. *Point/Wave,* on the other hand makes use of staff notation, but is congruent with *Svevning* in including Roman numerals denoting natural harmonics, and cent deviations from 12-TET. The score for *Point/Wave* also shows string number, enabling the performer to read the score without relating to the staff notation, almost as the tablature form, but without the tablature layout of six lines representing a string each. Shown below are the two first lines of the score for *Point/Wave* (Lamb, 2015):



A combined difference between, and similarity of the two pieces is the shared inclusion of added sonic elements to the solo guitar format – differing between the pieces in their respective sonic and technical natures. While *Svevning* includes the humming voice of the performer, *Point/Wave* includes an electronic setup that the composer calls *the environmental chord cycle*, producing an ethereal soundscape interacting with the guitar. The setup consists of a microphone situated outside the space of performance, with its signal sent through a (self-developed) computer application filtering the sound of the environment in a way that highlights the frequencies of the guitar tuning/material. Since the *environmental chord cycle* is a sonic alteration or extension of the environment outside the performance space, the sound changes dynamically corresponding to the environmental sounds, like a sonic ocean wherein the plucked guitar tones can intersect like rippling droplets. *The environmental chord cycle* is a beautiful way of bringing in the outside environment and letting it become a part of the music in real time, also encompassing the chance element, or the unpredictability of the environmental sounds.

In *Svevning,* on the other hand, the voice has both similar and different qualities to the *environmental chord cycle*. Contrary to the continuous sound of the latter, the singing in *Svevning* is only occurring occasionally, but they are similar in that the singing also comprises a (more) sustained sound that the guitar plucks subtly interact with.

Inasmuch as both pieces consist of rubato phrases and chords employing exclusively open strings (with a few exceptions in *Point/Wave*) and natural harmonics, the two pieces vary in many ways, e.g. which elements are composed and which are open to the performer or to chance. All the melodies and chords in *Point/Wave* are scored in a chronological manner, and

what is left open to the performer is the phrasing, tempo and to some extent dynamics of the music. In *Svevning*, the harmonic unfolding is organized chronologically as well, but contrary to Lamb's piece, and as discussed in section 4.1.5, the harmonic material and the combinations of strings are the only fixed elements, while the remaining parameters – how to pluck the strings, form chords and melodies etc. is just loosely instructed:

> The ways in which the strings are plucked, rhythmically as well as dynamically, is an open element of the piece. However, as a general rule, the performer should create slow repeating motifs where both successions of single strings and strings struck together in dyads, triads etc. are occurring as part of these motifs. The motifs will naturally change in relation to how many notes are to be played in each section.
> (Rasten, 2023, p. 4)

The motifs, chords and melodies that the performer is instructed to create from the harmonic unfolding is first and foremost conditioned by the amount of strings in play at any given stage of the piece.

Point/Wave and *Svening* respond differently to each of the research questions. Regarding both the approach to guitar (research question 3), and the organization elements (research question 1), the most important differences are the fixed versus changing tuning and the diverging use of improvisational elements. Whereas *Point/Wave* uses a singular tuning and a thoroughly composed musical line of melodies and chords as a framework for deeply exploring the sonic potential herein, *Svevning* uses an ever-changing tuning as a means of realizing just harmony on the guitar, and in a way where only the harmonic unfolding of the strings are scored, and where realizations in principle can contain a higher degree of variation both between different iterations and internally in each one, because of the improvisational/open approach to creating motifs, chords and melodies. In both instances, JI is conditioning the *organization* of the harmony, i.e its horizontal and vertical unfolding. Concerning *structure and perception* (research question 2) – as discussed in section 4.1.5., the relations or *connections* between structure and perception connected to *Svevning* can be summed up in the concept of tunability, since the music relies on real-time tuning. In *Point/Wave*, on the other hand, tunability is not applying, as no real-time tuning takes place. However, the particular

harmonic qualities of the guitar tuning and the *environmental chord cycle* naturally contains connections between structure and perception of JI, because these harmonic qualities can be *conceptualized*, as tonal relations, prime-limits etc., they can be *perceived* in listening, and their horizons can *synthesize* into a coherent experience. A mutual intention of exploring the sonic qualities of JI through a quite minimalistic and restricted approach to sound and technique is evidently a shared key quality between the two pieces.

4.2. Case studies (II) – *Harmony for six voices*

Harmony for six voices is another of my early compositions in just intonation which has developed in stages - the original version from 2017. This piece is shorter than *Svevning*, between 6 and 10 minutes in length, and intended for an ensemble of open instrumentation, capable of producing sustained notes. As such, the piece does not necessitate a specific guitar approach, and research question 3 will hence not be directly addressed here. The first two sections will focus on two concrete theoretical matters, namely *wolf* intervals and Pythagorean tuning, where from the subsequent sections will employ theoretical insights for analyzing the piece. Altogether, the discussion will address research question 1 and 2, as it will demonstrate how the piece is *organized* through JI principles, and how it is *conditioned* by relations between structure and perception. At the end of the chapter we will look at the piece in comparison with Marc Sabat's *Gioseffo Zarlino*, as they both have a focus on the syntonic comma and prime limit 5.

4.2.1. Guitar tuning, wolf fifth and syntonic comma

While the guitar is not itself an integral part of this finished piece (as *object*), it was an integral part of the *process* of composing the piece. Moreover, the idea for *Harmony for six voices* originated in exploring a variation of the *D-tuning* used in *Svevning* (described in section 4.1.1), with the 2nd string tuned as a 5/3 B to the reference string D, instead of a 7/4 C, as in *Svevning*.

The resulting tuning information is shown in the following table:

String	Frequency in hz	Note with cent deviation from 12-TET	Ratio to D (146,66 hz)	Ratio to common fundamental G (6,11 hz)	Prime limit
1	275	C# -14	15/8	45/1	5
2	244,43	B - 18	5/3	40/1	5
3	165	E +2	9/8	27/1	3 / Pythagorean
4	146,66	D -2	1/1	24/1	2
5	110	A +/-0	3/4	18/1	3 / Pythagorean
6	91,66	F# -16	5/8	15/1	5

A main *structural* change caused by swapping the septimal 7/4 C with the 5/3 B, is a *modulation* of the common fundamental frequency. From the column “Ratio to D (146,66 hz)” we see that every pitch except B relates to D either as the fundamental (1) or as an octave of it (2, 4 or 8), whilst the newly introduced B relates to D as a 5 over **3** relationship. Consequently, since D relates as 3 to G, the fundamental (1) of this ratio is G (and B-G-D altogether makes a 5/3/1 relationship). Similarly to the tuning table for *Svevning*, the “Ratio to D..” column denotes the relationships of each string to the reference string/pitch D, whereas the “Ratio to common fundamental..” column puts us in the perspective of seeing how all the pitches relate to their *common* harmonic series, which, by the change from the 7/4 to the 5/3 of the 2nd string, has *modulated* from D to G.

Each row of this tuning table relates to the research questions. The first row denotes guitar strings by number, and tells us that we are addressing a way of working with JI on guitar that takes retuning of open strings as a starting point (addressing research question 3). The remaining rows are all different modes of measuring or conceptualizing aspects of JI, and as such comprising *structural* features of JI. Hence, we are addressing research question 2 when we pair these theoretical conceptions with their corresponding sounds in our acquisition of JI knowledge.

Harmony for six voices is based on a classic tuning problem in 5-limit just intonation, namely the occurrence of the out-of-tune sounding *wolf* fifth when combining primes 3 and 5. As it occurs in the tuning in question – when sounding the 5 of the 5/3 and the 9 of the 9/8, where the denominators, i.e. 3 and 8, of the respective ratios are referring to the same note (D), we achieve this "mistuned" fifth with the ratio **40/27**. We see this interval's occurrence in the "Ratio to common fundamental"-column between the second and third string (as described in section 4.11, we can ignore the shared denominator/fundamental to find the rational relation between each string). The wolf fifth 40/27 gives us another entry point to the *syntonic comma* that we have already described earlier as the intervallic difference between the *Pythagorean* major third, derived from 4 stackings of just fifths, and the 5-limit major third derived from the fifth harmonic 5/1. We will here derive the syntonic comma by comparing 40/27 with 3/2, through a few arithmetical steps:

1. 27 x 3 = 81 We are multiplying 27 by 3 to reach its 3rd harmonic
2. 81 / 27 = 3/1 The interval between 27 and its third harmonic gives the ratio 81/27
3. 27 x 2 = 54 We multiply the denominator, 27 by 2..
4. 81 / 54 = 3/2 ..to find its octave/2nd harmonic, arriving at 3/2 **expressed as** 81/54

Through these operations, we are expressing the interval 3/2 with 27 as the fundamental pitch (1 x 27). As shown, 3/2 expressed this way gives us the ratio **81/54.**

Our initial interval under scrutiny was 40/27, and by multiplying both the numerator and the denominator of the ratio by 2 we thereby align the two intervals in question, giving them the shared reference/denominator (54):

5. 40 / 27 x 2 / 2 = 80/54

We see that the difference between a just fifth 3/2 (expressed as 81/54) and a wolf fifth 40/27 (expressed as 80/54) equals **81/80,** which is the syntonic comma.

Consequently, 40/27 is the just fifth (3/2) reduced or "narrowed" by the syntonic comma.

It is crucial to note here, that in multiplying both the numerator and the denominator of a ratio with the same number, the ratio/interval *proportionally* remains the same, i.e. as a relation between two notes. Hence 3/2, as a *proportion*, is the same as 81/54. This method for finding the intervallic difference between two intervals involves multiplying one of, or both, the intervals with whichever whole number that gives them the *least common denominator*. When the two intervallic ratios thus share one denominator, they are expressed in a way where we can compare their numerators, revealing the ratio *between* them.
Here we can make an analogy to visual perspective – to compare the sizes of two objects, they must have the same distance to the observer, and the shared relative distance in this analogy corresponds to the sharing of denominator/reference between two ratios to illuminate their proportional differences.

As we have seen in section 3.7., another way of finding the difference between two intervals is to *divide the larger interval by the smalle*r, which again, is the same as *multiplying* the larger interval with the *inverse ratio* of the smaller interval. This operation gives us the same result:

3/2 : 40/27 =
3/2 x 27/40 = 81/80

This latter method is methodically a simpler way of deriving intervallic difference. However, both approaches render different insights into the structures of JI, when conceptualizing it as interrelations of rational proportions. The first method renders insights into how multiplying both numerator and denominator of a ratio with the same number places it elsewhere in the numerical framework, but otherwise *retains* its proportional value. The second method results from the logical opposite of the fact that adding ratios together entails deriving their *product*. Hence – subtracting one ratio from another entails deriving their *quotient* (as discussed in section 3.7.).

4.2.2. *Pythagorean* tuning and its relation to 12-TET

As stated in relation to the HEJI-system (in section 3.10.), the Pythagorean or 3-limit system can serve as *the basis from which the other higher-prime relations can be denoted as*

deviations. Firstly, this is because it takes the simplest (non-octave/non-unison) consonance as its building block, and, secondly, because it closely resembles 12-TET, which makes it especially viable from a western point of view where we are used to conceptualizing and hearing harmony in the equal tempered framework. To tie this discussion back to the piece *Harmony for six voices*, this modulates back and forth between two harmonic planes having *Pythagorean* G and E as their respective fundamentals. In the following we will have a closer look into how this modulation works, with a parallel focus on this particular instantiation of Pythagorean tuning, and this tuning system more generally. Since the Pythagorean system is based on accumulation of 3/2 fifths, we find the interval between G and E through the cycle of fifths, which we know from western music theory. More precisely, we reach E by 3 *ascending* fifths from G:

(G) - D - A - E

Hence, in the language of ratios, we have to derive the *product* of three 3/2 intervals:

3/2 x 3/2 x 3/2 = 27/8

We reach the interval 27/8, which spans one octave and a (Pythagorean) major sixth. In JI theory it is normal to categorize the intervals in their *normalized* form, i.e. within one octave. This is also called *octave reduction*.

To reduce 27/8 by one octave (2/1) we reduce the larger interval (27/8) by the smaller (2/1), which, as demonstrated in section 3.7., amounts to *multiplying* the larger interval with the *inversion* of the smaller:

27/8 x 1/2 = 27/16

We reach 27/16, which is the Pythagorean major sixth. Furthermore, conceptualizing intervals as inversions of each other is useful both in normal music theory based on 12-TET and in JI. And to find the *inversion* of this major sixth, this amounts to finding the interval between 27/16 and the octave, and hence a repetition of the operation of octave reduction.

Again, we reduce the larger interval, the octave (2/1) by the smaller interval, 27/16, i.e. multiplying the former by the inversion of the latter:

2/1 x 16/27 = 32/27

Altogether, we see that the (normalized) interval between Pythagorean G and E is the Pythagorean major sixth **27/16** or its inversion, the minor third **32/27**. Both these intervals are quite complex, which is evident from the relatively high numbers. Since there exist simpler consonances in the same interval groups that have a stronger "attraction" to, or "gravitational force" on our ears, these pythagorean versions of sixths and thirds are harder to tune, relative to the simpler intervals. These are instances of the general rule that the smaller the numbers of an intervallic ratio are, the more tunable is the interval in question. As examples of intervallic equivalents that are (rationally) simpler than the Pythagorean thirds/sixths, we can look at the 5-limit and 7-limit minor third and their inversion, major sixth:

5-limit minor third: 6/5
5-limit major sixth: 5/3

7-limit minor third: 7/6
7-limit major sixth: 12/7

These consist of smaller numbers, and are arguably easier to tune than their Pythagorean equivalents:

3-limit (Pythagorean) minor third: 32/27
3-limit (Pythagorean) major sixth: 27/16

Again, these are examples of a relation between JI perception and structure, where the two realms, one *experiential*, the other one *cognitive*, mirror each other's *complexity.*

As mentioned (in section 3.10 and the start of this section) there is a resemblance between 12-TET and the Pythagorean system. Moreover, 12-TET can be described as an

approximation of the Pythagorean system, bypassing a "flaw" with Pythagorean tuning, namely the *Pythagorean* comma. This comma is the interval *between* the arrival note of a full 12-step revolution of a Pythagorean cycle of (3/2) fifths, *and* 7 octaves (2/1 ratios).
To find the ratio of the Pythagorean comma, we have to multiply a *fundamental,* 1, by 3/2 twelve times:

(1 x) 3/2 x 3/2 x 3/2 x 3/2 x 3/2 x 3/2 x 3/2 x 3/2 x 3/2 x 3/2 x 3/2 x 3/2 x

= 531 441 / 4096

To find the discrepancy between this ratio and 7 octaves, we multiply a fundamental by 2/1 seven times:

(1 x) 2/1 x 2/1 x 2/1 x 2/1 x 2/1 x 2/1 x 2/1 = 128/1

Here we have two ratios. But it is still difficult to see the discrepancy between them, since the magnitudes of their numbers are so different on both sides of the fraction. To see how these two numerators relate to *each other* and not only to their respective denominators, we must multiply both the numerator and the denominator of the latter ratio by 4096, hence making both ratios have a shared denominator:

128/1 x 4096/4096 = 524 288/4096

Now having a shared denominator between the resulting ratios, we can compare their numerators to find their intervallic difference, i.e. the Pythagorean comma:

531 441 / 524 288

As these are very high numbers, the proportional properties of the comma is hard to make sense of. However, it is still evident that the number of the numerator is higher than the number of the denominator. And the numerator is the result of 12 stacked 3/2 intervals, while the denominator is the result of 7 stacked 2/1 octaves. As we know from the cycle of fifths –

in taking the note C as a starting point, these two operations render the two notes C (octave) and B# (augmented seventh). In the Pythagorean system the difference between the two notes is an integral part of the tuning, while in 12-TET the two notes coincide in pitch, while *retaining* their functional and structural differences in the theoretical organization of the notes. Hence we see how the 12-TET system appears as an approximation of Pythagorean tuning: each of the twelve accumulating 3/2 fifths are reduced by a twelfth of the comma, with the result that a full revolution of the 12-TET cycle of fifths adds up to a perfectly in-tune octave, nullifying the comma between C and B#.

The Pythagorean comma is an example of how commas are instances of the overarching logic/dynamic of JI, and more specifically the fact that two different primes cannot yield the exact same intervals. While the syntonic comma 81/80 differentiates prime-limits 3 and 5, the Pythagorean comma identifies the difference between prime-limits 2 and 3.

This discussion has exemplified how structure and perception of JI/rational intervals coincide, through a comparison between Pythagorean and equal tempered tuning. It is the structural features of Pythagorean tuning that results in its corresponding comma between the octave and the *augmented seventh* which evidently is perceived in our hearing.

4.2.3. The *syntonic comma* as organizing principle

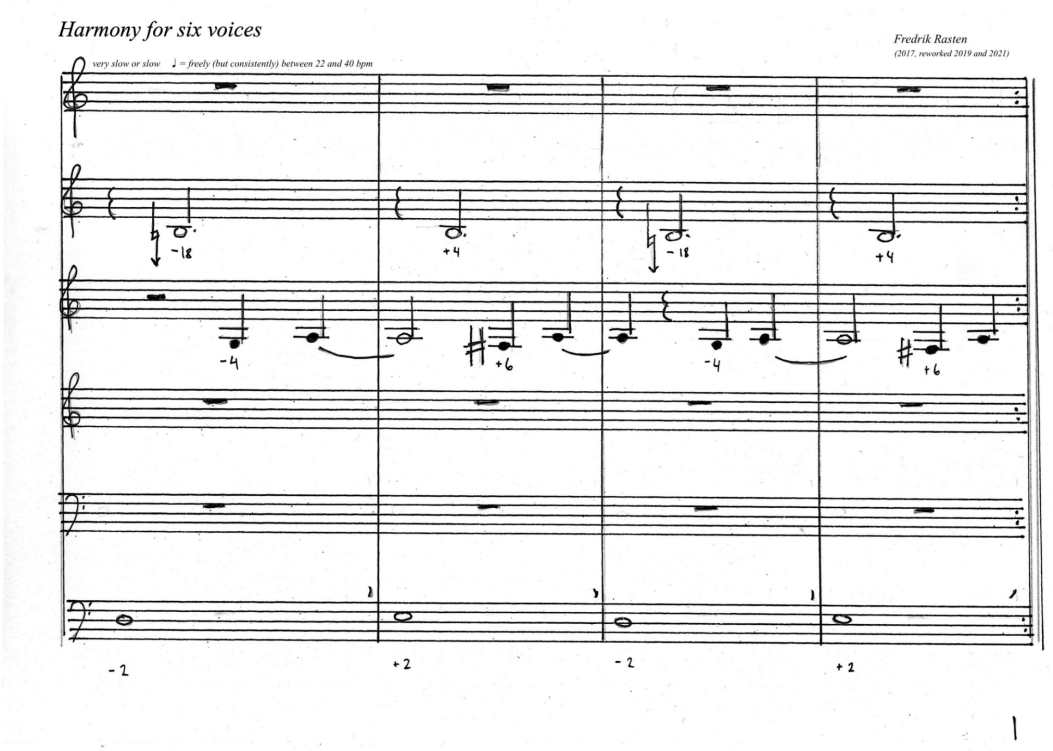
Having established some facts of Pythagorean tuning, we can return to the piece *Harmony for two or more voices,* demonstrating how modulations between Pythagorean relations can take place. We will also see how the *syntonic comma*, i.e. the difference between 5-limit and Pythagorean tuning, plays a key organizing role in this piece. The main elements of the piece is the back-and-forth modulation between the two tonal planes G and E, separated by a Pythagorean minor third (32/27), and the ways in which these two tonal planes generate the *syntonic comma* (81/80), in their respective rational relations to the note B. This process can be explained in the following way:

As B makes a major third with G, we know that the *Pythagorean* B needs to be reduced by the syntonic comma to make the 5/4 to the (Pythagorean) G. However, as B is the fifth of E,

it needs to return to its Pythagorean "position" to make an in-tune fifth (3/2) with the (Pythagorean) E – otherwise producing the *wolf* fifth 40/27, as explained in section 4.2.1.

This explanation gives us the structural layout and working of the syntonic comma. However, how the modulation itself can be performed by exact JI measures, is yet to be explained. Since the relation between the harmonic planes (32/27) is not a basic tunable interval (as discussed in section 4.2.2.), the modulation between G and E needs to be bridged by a note that makes a basic tunable intervallic relation with both G and E – we can call it a harmonic *mediator*[8]. The "mediating" note suitable for this task is the Pythagorean note A. This A is the 9/8 of the G, and especially in combination with D, it creates the tunable (Pythagorean) suspended triad comprising G-D-A, or in rational terms expressed 4/6/9. Being the 4/3 of E, A is thus also a basic tunable relation to E. Note that in the 4/3 that A makes with E, A is 4 and hence the (octave of the) fundamental, meaning that when A is sounding, the tonal plane is A-fundamental. However, as soon as we have tuned E from the "mediating" A, the A can fade away, and thereby making E the fundamental of the overall chord. Here we have closely explained how A serves as a mediating/connecting note between the (Pythagorean) G and E, thereby enabling this modulation. Having explained both the working of the syntonic comma in this modulation, and how the modulation itself is achieved, we can see how the combination of these elements comprise a musical unfolding structure in this score excerpt showing the first four bars of the piece (Rasten, 2021):

[8] This is my own term used here for descriptive purposes, and not a part of JI- or general music terminology, to my knowledge.

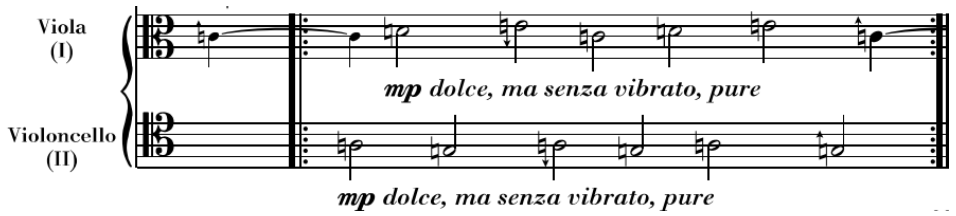


In these four bars, the 6th voice (from the top) moves by 9:8, shifting between the Pythagorean notes D and E, as parts of the movement between the two harmonic planes G and E. To make the modulation tuneable, the 4th voice provides the necessary notes both identifying the harmonic plane, and enabling the modulation. The initial G in this voice, identifies the harmonic plane as G, and in moving to A, which is simply tunable with the sounding D in the 6th voice, the transition from D to E in the 6th voice can be achieved, with the A as a mediator. When the 4th voice moves from A to F#, the tonal plane of E is established, before A returns as a mediator back to the G-plane. As we can see, the B's moving back and forth in the interval of the syntonic comma occur in the 3rd voice. The piece stays in 5-limit for its first half, before higher prime notes (7, 11 and 13) enter and create a more microtonal timbre. However, we will not cover these aspects of the piece here, as this case study focuses on the structural aspects of Pythagorean and 5-limit tuning, exemplified through usages of the syntonic comma. We will finish this case study with a comparison between my piece and a composition by Marc Sabat.

4.2.4. Comparison between *Harmony for six voices* and Marc Sabat's *Gioseffo Zarlino*

A piece that has been an inspiration for my work with JI and that also works with syntonic comma modulations is the piece *Gioseffo Zarlino* by Marc Sabat. The piece is dedicated to the renaissance composer with the same name, who advocated for just/pure thirds and sixths – what is now known as 5-limit tuning. Zarlino (1517-1590) was also a music theoretician, famous for his book about counterpoint composition *Le Istitutioni harmoniche* from 1558. Sabat's composition is a part of a series of pieces where he pays tribute to certain key figures from the history of tuning in western composition music.

The piece *Gioseffo Zarlino*[9] has at its core a *counterpoint* between two voices, realized by cello and viola. The piece contains other instruments as well, whose roles and musical material we will not cover here, since the aim of this comparison is to demonstrate the usage of 5-limit tuning and the syntonic comma in the harmonic unfoldings of the two pieces.
This excerpt shows the described counterpoint in the first bar of the piece (Sabat, 2015):



The first note is a Pytyagorean A in the cello, followed by a C in the viola, but as we see from the natural accidental with an upwards arrow, this C is *raised* by a syntonic comma from its Pythagorean intonation, to the simpler and more tunable 6/5 or 5-limit minor third.
The viola ascends by a 5-limit wholetone 9:10 from C to D, thereby completing a 4/3 ratio with the A of the cello. Thereafter, the cello voice descends by a Pythagorean whole tone 8:9 to G, making a 3/2 with the D, before the violin ascends by a 9:10 to E lowered by a syntonic comma, tuning it as 5/3 to the G. The cello moves upwards to A lowered by a syntonic comma, tuning it as a 3/2 fifth with the viola's E. At this point, the A is tuned one syntonic comma lower than the initial A at the start of the bar. Through these 5-limit "pathways" the

[9] Audio released on Sacred Realism (SR010) in 2020 (Sabat, 2020)

two voices create a beautiful and sonically striking music that demonstrates how instances of 5-limit modulations include the syntonic comma and its corresponding differing intonations of the "same notes". Both Sabat's piece and my own have this feature, and they also share some other musical qualities, e.g. in the repetition of musical "cells". In Sabat's piece, the repetition consists of alternating movements between the two instruments in sounding 5-limit dyads. In my piece, the repetition consists of the recurring modulation between the two harmonic planes of G and E, with the A as a "mediating" note/harmonic plane.
The two pieces also demonstrate different ways in which the syntonic comma or 5-limit modulation can have musical significance. Where Sabat's piece melodically uses both the Pythagorean and the 5-limit wholetone, 9:8 and 10:9, to realize the modulations, my piece includes a voice sounding the Pythagorean comma itself as a combined melodic and harmonic element. Correspondingly, in Sabat's piece the modulations appear more *concealed*, while in my piece the melodic back-and-forth movement of the syntonic comma makes the modulation more sonically present. Both pieces provide answers to research question 1 and 2. The syntonic comma is a JI element that is used as an *organizing principle* in both compositions, and as it is harmonically structured in ways that make it *tunable* in both pieces, it is an example of a connection between *structure and perception* in JI. Again, structural and perceptual knowledge complete each other in the coherent whole of tuning and navigating JI harmony.

4.3. Case studies (III) – *Murmurations*

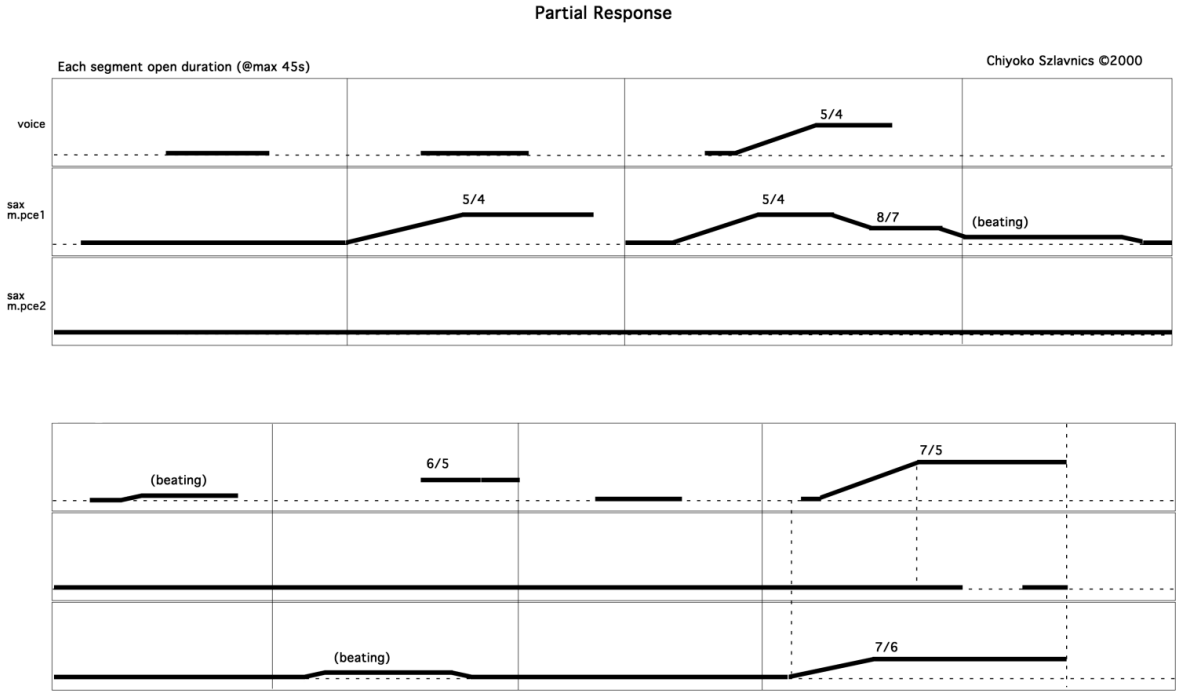
This third case study covers some key elements of my series of pieces called *Murmurations*. These pieces are composed for an idiosyncratic setup of guitars played with *Ebows*[10], and will therefore be particularly linked to research question 3.

4.3.1. Forming a new instrumentarium with Ebows

I have worked with Ebows as a means for making sustained tones on guitars for many years – and often in combination with slides/tone bars, to bypass the restriction of the 12-TET frets. In 2020 this practice reached a new level when I got the opportunity to rework the piece

[10] An Ebow is a device that makes strings with a magnetic core vibrate indefinitely by inducing an electromagnetic field.

Partial Response (2000) by composer Chiyoko Szlavnics (1967 -). The piece is originally composed for a trio of two alto saxophone mouthpieces/necks, and a mezzo-soprano voice. However, since the score merely consists of rational relations without a fixed reference pitch, the piece can in principle be realized with any instrumentation capable of realizing these tonal relations. Here is the first page of the score showing the pitch relations and the ways they are conveyed (Szlavnics, 2000):



As we see here, Szlavnics uses graph-like lines to denote changes of pitch, and ratios to denote the tonal relations, as well as implementing undefined small intervals with the effect of creating occasional pulsating beatings – another example of a minimal JI material subtly making use of the *contrast* between JI sound and interference. The guitar setup that I developed for this piece consists of three Ebows on a fretless acoustic guitar with small objects (wooden- or plastic pegs) serving as movable bridges under each of the three sounding strings, hence enabling the possibility for flexible intonation of the strings. Furthermore, to ensure that the Ebows are continously fed with electricity, the normal 9 volt batteries for the Ebows are swapped with adaptors, feeding them with electricity from normal 220 volt outlets. This solution has at least two advantages. Firstly, I do not need to worry about the Ebows running out of power, secondly, I can turn the Ebows on/off individually using a multi-outlet extension cord with individual power switches for each outlet – with a

resulting increased control over the individual tones in the overall harmony. Since 2020 onwards this specific way of guitar playing has been very impactful on my work with JI and guitars.

Photo from a concert performance of *Partial Response* by Chiyoko Szlavnics at KM28 in Berlin. The photo shows the setup with three Ebows on one acoustic guitar, movable pieces under strings, and the left hand technique with a metal tone bar. Photo: Mareike Lee.

4.3.2. Formal principles in *Murmurations*

To this date the *Murmurations* series consists of 25 pieces, all composed between 2020 and 2022. They are intended for varying guitar setups with Ebows, sometimes also including my own voice:

Murmurations I-V: for acoustic guitar and voice (in four part harmony with three strings played with Ebows in addition to voice)

VI - XII: for two acoustic guitars (in six part harmony, with six strings played with Ebows)

XIII - XV: for two acoustic guitars and voice (in seven part harmony, with six strings played with Ebows in addition to voice)

XVI - XX: for two electric guitars (in six part harmony, with six strings played with Ebows)

XXI - XXV: for two electric guitars and voice (in seven part harmony, with six strings played with Ebows in addition to voice)

There is a consistent harmonic line of structure going through all the pieces, also operating cyclically throughout the whole series of *Murmurations*. Firstly, each succeeding piece starts in the harmonic material where the preceding piece ends. Secondly, each *cluster* of pieces start and end in the same very same harmonic material, giving each cluster a cyclic form internally, and connecting the clusters together into the whole of all the pieces. The individual pieces hence comprise parts of cyclical wholes on two systemic levels – both belonging to the *clusters* of pieces with a shared instrumental setup, and to the totality of all 25 pieces. Connected to performance, a pragmatic dimension of this is that the performer does not need to retune the guitar(s) between pieces, hence enabling multiple pieces to be performed in an uninterrupted flow. And a formal dimension is the idea that succeeding pieces can be tied together in a form of indefinite duration. This is an example of an interconnection between research question 1 and 3, in addition to the aesthetical idea of creating cyclic and long-form music with indefinite lengths – the combination of structural elements of JI and this specific guitar setup both *condition* and *enable* a music unfolding in this particular way.

Photo from a concert in Prague in 2021 with a performance of my composition *Concord,* for two ebowed guitars and sixth-tone harmonium. The picture shows one of the electric guitars in use, with movable “bridges" and played with three Ebows per guitar – a setup shared with some of the *Murmurations* pieces. Photo: Karel Šuster

Six electric guitars with Ebows as part of the latest iteration (2022-) of the *Murmurations.* Photo: Fredrik Rasten

The *Murmurations* are composed with a combination of an intuitive or improvisatory attitude and through structural “rules” concerning JI and tunability. The *first* piece in a subseries

always starts in a chord/dyad with a high degree of tunability and feeling of consonance. This normally means that the harmony is built slowly, starting with Pythagorean or 5-limit sounds and adding higher prime harmony after a while. Here, the idea that both the listener and the performer(s) can follow and enjoy the development or gradual layering of complexity is an aesthetic and formal guiding principle.

We will now see how the elements discussed thus far in this chapter relate to the research questions (section 1.2.), theoretical perspectives (1.4.) and methods (1.6.). Firstly, we see a connection between research question 1 and 2, in the way that structural elements of JI, more specifically a gradually developing harmonic complexity, is used as an organizing principle in the composition. Secondly, the ways in which these pieces can be linked together and create listening situations of indefinite lengths has consequences for the piece seen through Borgdorff's lens of *process*, *object* and *context* (as introduced in section 1.4.). Moreover, the pieces, seen as finished objects, can be given new meanings depending on how many and which pieces are linked together in a concert. Consequently, new listening *contexts* can be attributed to this music depending on the ways they are presented. Furthermore, when the audience members know that the *series* continues beyond the selection of pieces presented in a concert, they get a sense of the music as a vast *process* which they have just partially "witnessed", with corresponding influences on their experience of the music. Finally, regarding musical methods (as discussed in section 1.6.), we see examples of the compositional approach based on generating material from *improvisation* in combination with the approach based on *tuning theory*.

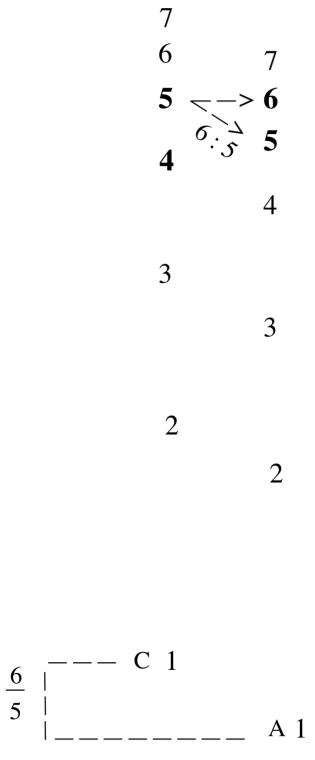
4.3.3. More on *modulation*

Modulation is a structural element of JI in my compositional praxis, and many of my colleagues in this field work with modulation in similar ways, as exemplified in Sabat's *Gioseffo Zarlino.* In this section we will have a closer look at how modulation works in the context of JI, before giving examples of it in one of the *Murmurations*-pieces.

Modulation can be described as the act of JI chords moving between their respective *conceptual* harmonic series, or *harmonic planes*, based on different *fundamentals*. In section 3.3., *Harmonic plane* was introduced as a framework encompassing the *conceptual* harmonic

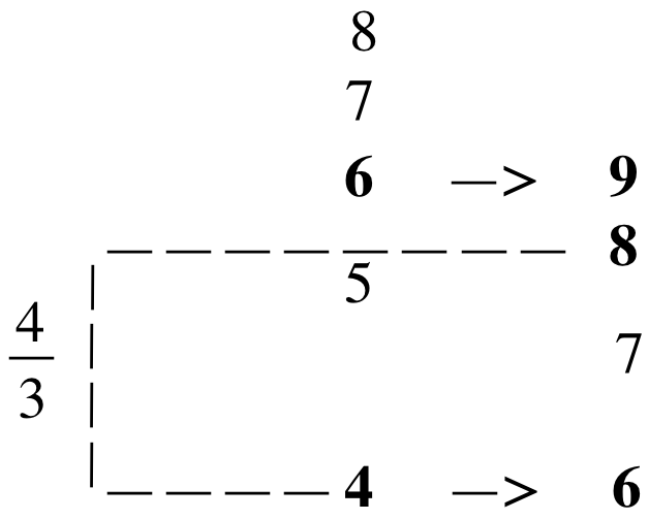
series wherein harmonic ratios can be described without confusing this framework with the harmonic series as a *sonic phenomenon* belonging to individual *generative* tones. Understood as such, modulation in JI is between *harmonic planes*. However, I will here revitalize the *harmonic series* or just *series* as a model of describing JI modulation, since it provides the most suitable illustrative entry points to this specific topic.

Generally, modulation is realized when taking a note belonging to one series, and, with that note as reference point, *rationally* tune another note *not belonging to the first series*, thereby instigating a segment of *another* series which is rationally related to the first because they share (at least) one note. To give a concrete example, the figure below (fig. 4) illustrates a modulation from one harmonic series to another.



More specifically, fig. 4 illustrates a modulation by a 6/5 interval from a C-fundamental series to an A-fundamental series (lowered by a syntonic comma from Pythagorean intonation). We see that **5** of the first series becomes **6** of the second series when a note **relating to it as 6** is introduced, in this example creating a 6/5 ratio in the new series.

Let us have a look at another modulation, the modulation between two harmonic series with an intervallic difference or *distance* comprising the most elemental interval (excluding octaves), namely 3/2. This figure (fig. 5) shows a modulation which is instigated by the introduction of a 4/3 ratio tuned from the fundamental of the initial series:

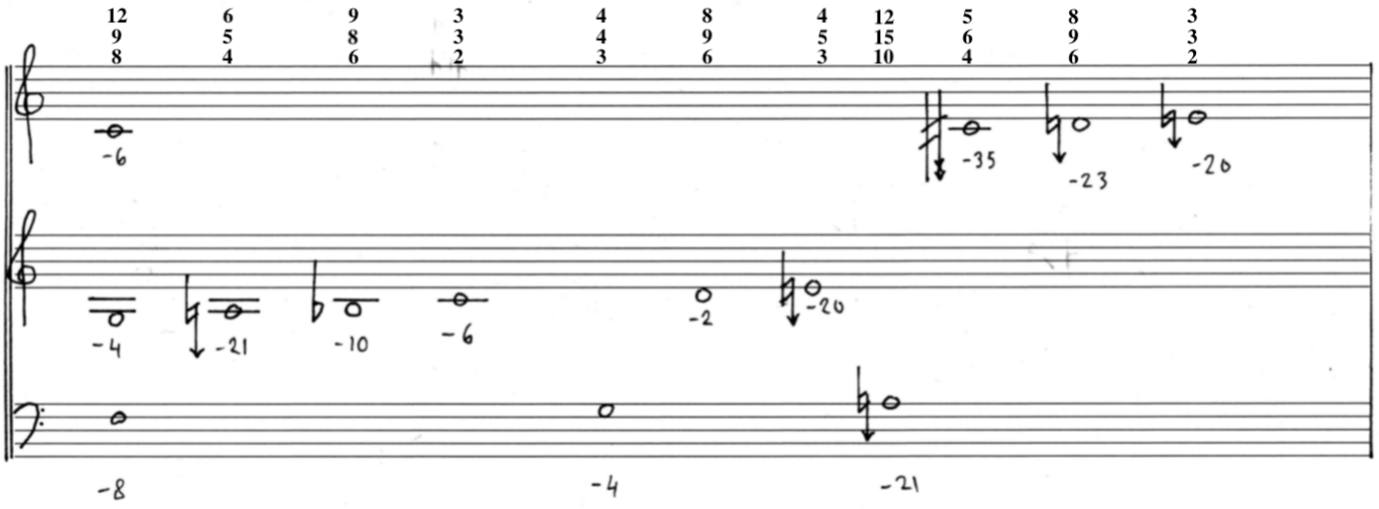


We see that the 6 in the first series (to the left) *becomes* 9 in the second (to the right), and similarly, that 4 in the first series becomes 6 in the second. Furthermore, the fact that the modulation is by a 3/2 proportion, is easily inferred because 3/2 = 9/6 = 6/4. However, how do we know in which *direction* (pitch wise) the modulation moves by the 3/2 proportion? As we know, multiplication is employed to add an interval to another and thereby achieve an *ascending* movement in pitch. Exemplified here, however, since the reference notes are *not* moving in pitch, but their harmonic number *increases*, the *fundamental* is consequently lower in the second series than in the first – this shift being constitutive of the modulation itself. Lastly, when a modulation or interval moves *downwards* in pitch as in this example, the arithmetical consequence of this is to flip the ratio, rendering this a modulation by 2/3.

Having demonstrated structural aspects of modulations in JI, we will now return to the *Murmurations* and see how modulation is applied in one of them.

4.3.4. Modulation in *Murmurations*

In this section we will bring the topic of modulations to an end by analyzing the modulations occurring in the first line from the score of *Murmurations I* (Rasten, 2020)[11]:



To start with the bottom voice, we see that for the first four chords, the held F in this voice is chronologically changing from being expressed as 8, via 4 and 6 to 2. When this note is expressed as 2, 4 or 8, the modulations in question are *octave modulations*. Octave modulations happen when we have an harmonic structure and add notes that are not expressible in whole numbers in the original octave. For instance, if we have the interval of an octave (1/2) and want to add the 3 inside this octave, this entails a modulation of an octave in the downward direction, creating the triad 2/3/4. The octave is now expressed as the relation between 2 and 4, and thus expressed, the 3 "fits" inside the scope of the octave. To take the transition between the first and the second chord as another example, the fundamental modulates up an octave when the 9 of the 8/9/12 is swapped with the 5 of 4/5/6. Because, to fit the 9 inside a 3/2 relation, we must transpose it downwards two octaves,

[11] Regarding the notation, the notes are sustained until taken over by another note in the same voice (or a pause, although no pauses occur in this excerpt). Also, note values do not apply here – the music unfolds slowly without a metric/rhythmic component. The numbers placed vertically on each chord show the individual rational relations for each chord, reduced to their simplest terms, organized by the order of the voices in the score (not by harmonic number). These rational relations denote the modulations as they unfold (these numbers are not parts of the original score, but added as part of this analysis).

making the entire triad expressible as 12/9/8. The 5, on the other hand, can first fit inside the scope of the 3/2 after modulating an octave upwards, expressing the entire triad as 6/5/4. Arguably, octave modulations are not "full-fledged" modulations, since octaves in a sense lack *harmonic significance*. In music theory octaves are identified as sonic iterations of *the same* note – differing in pitch height, but essentially sharing a sonic identity. On this background, the first full-fledged modulation is exemplified in the 3rd chord in the excerpt, with the fundamental modulating (downward) by a 2/3 ratio. Again we see that 4 becomes 6 and 6 becomes 9, simply by adding the Bb that makes a 4/3 to the F, thereby introducing the new fundamental Bb.

The rest of the excerpt includes further modulations. For instance, when the A (lowered by a Pythagorean comma) is introduced in the bottom voice we have modulations by the introduction of every succeeding note: first upwards by a 10/4, then downwards by 4/6, then upwards by 6/2. As the 2nd and 3rd voice is statically held for these last three chords of the excerpt, we can infer that it is the movement of the first voice that instantiates the modulations, while the held notes are shared between the *conceptual harmonic series* (plural) in which the respective chords comprise segments. Again, it is the *fundamental pitches* of these *conceptual* harmonic series that move in the modulations instantiated in the three chords in question. These fundamental pitches are not themselves sounded, but they are parts of the *structural* foundation of the harmony, *and* can be *perceived* subtly as difference tones or rational beating (as discussed in section 3.4.).

This analysis of *modulation* has demonstrated its *structural* aspects and how these can serve as an *organizing principle* for composition. Specific to modulation, a relation between JI structure and perception is when one can *perceive* the harmonic shift in the modulation (e.g. the perception of 6 becoming 9 etc., referring to the modulation in fig. 5., section 4.3.3.).

4.3.5. Further views on tuning and composition

Referring to the case study on *Svevning* (4.1.), my main approach to composing is creating JI frameworks, where the harmonic structures are composed, while the remaining elements are either improvised or subject to habits of realization. This approach is also used in *Murmurations.* The harmonic unfolding is composed, but the ways of shaping the music, the

dynamics, the time spent in each sonority etc. is open to the performer. Contrastingly though, *Svevning* and *Murmurations* have very different ways of *realization*, since the former is played with plucked open strings on an acoustic guitar, while in the latter the Ebows are continuously activating the strings until they are actively shut off. However, in both pieces comprising *JI frameworks* – as described in section 4.1.5, they contain similar open elements directly connected to, and conditioned by, the process of tuning.

Contrasting with the non-rhythmic, freely sustained/repeated harmonic material in the two solo pieces, *Harmony for six voices* (section 4.2.) is contrasting, in that it includes a metric rhythm – indeed a slow one, but anyhow dictating the durations of tones. The inclusion or exclusion of metric rhythm are two different methods of connecting JI harmony to the realities of enacted music. And as long as the *process of tuning* is cared for, conditioning also the rhythmic aspects, the diverging approaches render different ways of relating to the process of tuning. Inasmuch as sustained harmony without metric rhythm provides perfect conditions for a slow and *gradual* process of fine tuning, a metric rhythm, serving as a temporal reference, can also benefit the tuning process, as musicians can navigate the tuning relative to the rhythmic pulse. In the example of *Harmony for six voices* for instance, with the notes appearing and leaving in the framework of a metric rhythm, without being as sustained as in the other examples of piece, and the voices having more individual roles in the weaving of an harmonic but also more *melodic* structure, this gives a certain focus and urgency to the task and *process* of tuning.

4.3.6. Preliminary conclusions and research overview

At the present point in this text we have already described multiple instances of answers to the research questions through harmonic analysis and descriptions of JI theory, in itself, and through compositions. In the following we will cover two different angles belonging to this research, namely, *spatialization* of JI sound (in the piece *Six Moving Guitars*) and its implication on the research questions, and, *experiential, social and human aspects of just intonation* (in chapter 5). While the former topic belongs more directly to the research as thus far conducted, the connections to the latter calls for some further clarification. In addressing the way that JI and *tuning as process* conditions the possibilities to *organize composition* (as in research question 1), we highlight the close relation between the pragmatics of tuning by

ear and the potential beauty *in this very act*. An act whose attentiveness and way of listening is a *value* of this music that, besides the structural and perceptual elements outlined thus far, carries both ethical/social, phenomenological, and aesthetical meaning. It is aesthetical when we focus on its conditions for how the music is shaped and its corresponding potential *beauty*, and it is in varying ways both ethical, social and phenomenological when it suggests or shapes certain modes of *being with sound*, whose areas of analysis exists beyond the theoretical or structural elements of music, in posing questions about the relations between the music and the listener, between the performer(‘s listening) and the listener(‘s listening) etc.

4.4. Case studies (IV) – *Six Moving Guitars*

In this last case study we will focus on the sonic impact that movement and spatialization of sound sources has in combination with JI, as well as social aspects of music, in the piece *Six Moving Guitars.* While focusing on these matters, the analysis of the specifics of the harmonic content, the form and structure of the composition will be less extensive than in the preceding case studies.

Six Moving Guitars is a piece for six performers, playing open strings of a guitar each, while moving around in the performance space following a choreography that is integral to the musical composition. Since the piece grew out of a collaboration between three dancers and three musicians, and the idea was that all six performers play guitars, a premise for the piece is to be playable by non-musicians. This premise was partially pragmatic, but it was also closely tied to a *social* motivation – namely to create a situation focusing on specific ways of relating to each other through collective music making. An organizational element of the piece that is consequential both on a musical and a social level is its organization into three duos, where each member of a duo plays in rhythmical unison with the other duo member. Hence, no guitars are plucked individually – tonal entrances or plucks always occur together with a corresponding pluck in at least one other guitar. On a musical level, this results in a full sound that is always somewhat spatialized, since it comes from (at least) two different placements in the room. On a social level, this creates a dynamic where individuals are always simultaneously interacting with the whole group *and* with a duo partner. In the *intersection* between the two levels, this structure comprises both a musical and social “safety

net" – if an individual forgets or fails to perform a pluck, their duo partner will (hopefully) succeed in this task, and the pluck, as a part of the musical unfolding, is not lost.

In general, the piece endeavors to fuse ideas and elements from different disciplines into a coherent whole. We can categorize this in three two-part endeavors of fusing…

1 - …*aesthetic* and *social* concerns
2 - …*sound* and *movement*
3 - …music and choreography

Number 1 points to the endeavor that the piece should be simple enough for the performers to focus their attention to the totality of the sound, to their movements, their positions in the space relative to the other performers etc. Or, in other words - that the musical material is simple enough to enable the performers to shape the music and to relate to the other performers in an active and present way. The fusion of aesthetics and social concerns in this context becomes evident both on a conceptual and an experiential level - *the social interactions* and the inclusion of the possibility of non-specialist performers are in themselves *also aesthetic* elements of the piece, and the sound of the plucked tones and chords are sonic manifestations of the social interactions in play. In *Six Moving Guitars* specifically, point number 2 and 3 above both encompass the idea of combining acoustically produced just intonation harmony with movement and spatialization. Point 2 and 3 can on one hand be interpreted as interchangeable, but on the other hand they are also importantly separate because the four terms involved have different meanings – sound does not entail music and movement does not entail choreography, nor vice versa. When we describe an endeavor of fusing sound and movement, this specifically means that movement and sound co-occur in a way where they become integral to each other. In *Six Moving Guitars*, this happens when the sounds change because they are moved, and when the movements are *heard* by being manifested into sound. On the contrary, a fusion of the *artforms* of music and choreography have other criteria (semantically, culturally etc.) than the fusion of *sound* and *movement*, in and of themselves. We will not delve further into these distinctions, but note that the motivation for listing both point 2 and 3 above is to demonstrate some of the multiple levels and viewpoints from which one can analyze fusions of artistic expressions or artistic

expressions more generally, all of which, in the framework of artistic research, belong to Borgdorff's conception of *context.*

From a perceptual viewpoint there is a certain "paradox" in the endeavor of fusing just intonation sounds and movement. While JI sounds are characterized by a perceived *stability* and *clarity*, the moving of the sound sources around in a room creates sonic fluctuations which arguably obscure the clarity of the JI sound, relative to the speeds in which the sound sources are moved. However, from my experiences with *Six Moving Guitars,* the movements can also be perceived as *accentuating* certain qualities of the JI sounds. In the further discussion of this piece, and with concrete examples, the interplay between JI, spatialization and movement will be the crux of the matter.

4.4.1. The parts of *Six Moving Guitars*

The piece, which in total is around 40 minutes, is divided into five parts, each exploring different movements and ways of organizing the music.

1. Wandering: In the opening part titled *Wandering*, the music starts with the performers standing in a row facing the audience from the opposite end of the room, playing a slow pulsating motif consisting of plucks of single or double strings. The collective row of guitarists gradually moves forward before it dissolves when each player starts wandering around freely, filling the room with the sound of their guitar plucks while continuing to play together in a common pulse or metric time. As the movements here are all very slow, the issues/effects of fluctuations caused by the movements are minimal. The movements merely provide a slowly moving spatialization of the sound, where the audience members experience how the guitars and their sounds come closer and move away, both collectively and individually. The relative distances between the guitarists and the audience members also create variety in the perception of sound, created by each guitar individually and by the totality of them.

Screenshots from a video production of *Six Moving Guitars* published by Louth Contemporary Music Society in 2021. Video by Jenny Berger Myhre. (Louth Contemporary Music Society, 2021, April 15)

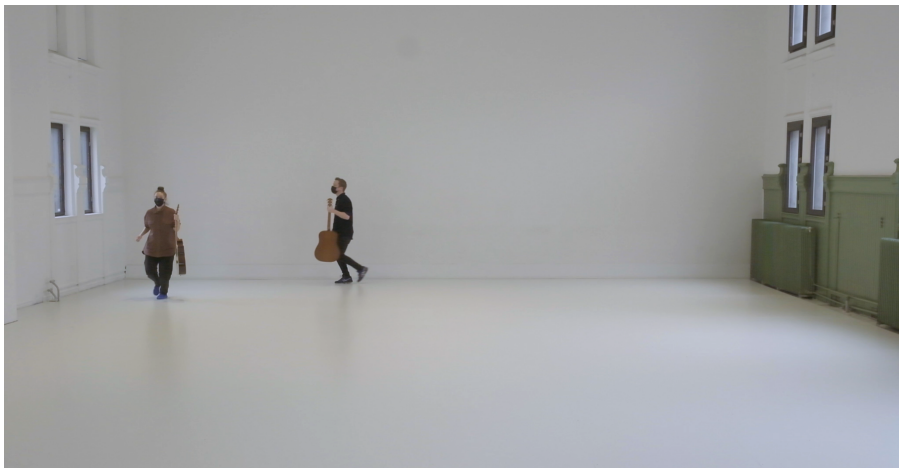
2. Circling: The start of this part overlaps with the very end of *Wandering*, when one of the performers starts to rotate around their own axis while holding the guitar by the nut and strumming a full chord, as shown below. The rotation is fast enough to make the guitar remain (close to) horizontal, held up by the centrifugal force of its own weight/inertia.

After a while this performer starts moving in a full circle in the room, continuing the rotation around their own axis, before being joined by another performer “mirroring” both the movements and the playing, always moving relative to the diametrical opposite of the imagined big circle filling the room. While the circular movement of the two performers comprise a moving spatialization similar to the walking in *Wandering*, the relation between movement and sound is more complex in *Circling*. The rotational movement of the guitars creates fluctuations in the sounded chord, resulting in a chordal sound that can be characterized as lush, obscured, wavy or liquid, while the simultaneous moving around in a big circle creates sonic differences relative to the ever changing distance to the audience members.

3. Circling, Alternating: *Circling, Alternating* is a continuation of the *Circling* part where the two performers playing *Circling* continue their unison groups of chords while simultaneously circling around in the room and rotating around their own axis – however, from this point onwards, with interspersed chords from the other four performers. These four are sitting still, either in the middle of the big circular path, or somewhere else in the room. Their exact positions, and hereby the *spatialization* of the sounds of their guitars, is an open or site-specific part of the piece. When we are focusing on the relation between movement

and sound, the sonic differences between the duo of circling/rotating guitars and the quartet of guitars that are not moving is the crux of the matter. The “lush” or “liquid” sounds of the moving guitars, in addition to their changing positions in the room, are very different from the clear and stable sounds of the guitar chords that are not in spatial motion. Altogether this creates a listening space, and an experience of the room where the “stillness” and the movements complete each other by being sonically and energetically contrasting.

4. Running: The fourth part, *Running*, takes a different approach to movement than the preceding parts. It includes four of the performers, or two duos, where each performer runs/joggs in a unison rhythmic pulse in circles around the room, striking guitar chords in relation to a 7-beat meter/pulse created by the unison steps.



Here, the relation between sound and movement is of a very direct nature, with running steps becoming rhythmic sounds in themselves, as well as having the role of organizing the rhythmic entrances of the guitar chords. The movements are also fast enough to make fluctuations in the perceived harmonic sound, but not to the same degree as in *Circling* or *Circling, Alternating,* where the guitars are fastly rotated. The running itself, and the rhythm it introduces becomes the strongest element in the meeting point between sound and movement in this part.

5. Pendulating: In *Pendulating,* the last part of the piece, all the performers coordinately strike full chords on their instrument while pendulating the guitar from side to side, holding it by the headstock (as shown on the picture below). The pendulations are as coordinated as possible, and function simultaneously as a time-keeper, with the chords entering on every 8th pendulating movement (occasionally, every 16th movement instead, on cue), and a sound effect impacting the sounds of the chords. In the totality of guitar chords, some of them coincide harmonically while others differ, with the resulting sound of a powerful and resonant cluster chord, repeated in such a slowly repeating pattern that the sound decays from its powerful impact into near silence, with fluctuations from the pendulating movements being integral parts of the sound.

The relation between movements and sound depends on both these fluctuations produced by the pendulations, and the fact that the pendulating itself is used to conduct the rhythm of the music. Evidently, *Six Moving Guitars* in its entirety is a very different experience live (or on video) than the pure sound of the recorded version[12], and especially in this last part, since the pendulations, and the way that they transparently conduct the entrance of the chords create a visually striking rhythm that fuse with the sound into an experiential whole.

4.4.2. *Six Moving Guitars* as choreography and activity

The movements in *Six Moving Guitars* are not given any extra-musical roles. Their purpose is to move the sound and thereby alter the sonic experience, for the performers and for the possible audience. The movements comprise a visual component, but since all movements are intended only to serve the sound, they come across as sonic/musical gestures, and not as mere bodily gestures. Hence we can say that the piece realizes a *sonic* or *musical choreography*. Regarding the social dimensions of the piece, an aim is that taking part in performing it feels like an *activity*, with elements of game, dance, sport, etc, instantiated through sound/music, movement and collectivity.

4.4.3. Just intonation in *Six Moving Guitars*

How do JI sounds combine with movement and spatialization in this piece?
The fluctuations created by the faster movements arguably create a "wavy" sound where the clarity of the JI harmony is obscured, but there is also a perception of an amplification or accentuation of JI qualities. For instance, the overtones seem to be highlighted because the waves in the sound and the way the sound sources move around make them more perceptibly distinguishable as individual sonic elements – different overtones and timbral elements are in focus depending on the movements and the proximity to the listener. Interestingly, also the stable and vibrant sonic quality of JI, i.e. the periodic "buzzing" sound of the lower register intervals, are perceived as accentuated rather than obscured, even in the faster movements of *Circling* and *Circling, Alternating.* Naturally, these views comprise a *synthesis* (in the hermeneutic meaning) of my own subjective experiences and more general traits of JI sound, formed from the research position that Borgdorff refers to as *in the arts*.

[12] Released by SOFA Music (SOFA573) in 2019 (Rasten, 2019)

How does this case study relate to the research questions? Firstly, *Six Moving Guitars* exemplifies a way in which JI can be used as an *organizing principle* in composition, in a music realized with acoustic guitars tuned to JI tunings, where the musical focus is on the fusion between JI harmony and spatialization/movement. In this piece, *tunability* is not a bearing element of realizing the harmony itself. However, the JI-specific sonic qualities of the produced sounds depend on the harmony being perceived as *in tune*. Hence, the connections between JI as *structured* and *perceived* is manifest in this piece also. Finally, the piece exemplifies idiosyncratic ways of approaching guitars in connection with JI, where openly tuned JI tunings enable open chords and collective melodic motifs that are combined with movements of the guitars and non-standard playing positions.

5 - Experiential, social and human aspects of just intonation

This research has focused on theoretical and experiential concerns relating to just intonation, with case studies of some of my pieces as points of departure. In *Svevning*, *Harmony for six voices* and *Murmurations*, the process of on-ear tuning of JI harmony is an integral part of how the music is organized, and its aesthetic intention. The performers' knowledge and perception of *stability* within the harmonic timbre, the absence of beating, and the rhythmic *buzz* of the JI sounds are some of the sonic "beacons" that make JI sounds feel like sonic gravitational points guiding the playing.

In this chapter I will focus more on these experiential and/or perceptual aspects of just intonation and use the insights from this research to establish the view that JI entails a unique mode of listening including both performers and listeners.

Evidently, the mode of listening it takes to perform this kind of music involves a state of mind that is highly concentrated on the task of hearing and comprehending JI harmony, i.e. recognizing both the rough outline of the chords or intervals, and subsequently fine tune them until they appear crystal clear. In the introduction to this thesis I mentioned the inspiration my music draws from Wandelweiser music, particularly from Antoine Beuger's music drawing on social or human aspects of music, and in this chapter we will look at the cooperative

workings of social and perceptual elements in JI music. As I see it, the perceptual aspects of JI tuning and music grants an intrinsic social element originating in the particular mode of concentrated listening it takes both to perform it *and* to listen to it. Importantly, music in general is social and communicative, and a striking aspect of music, as a temporal art, is the sound that unfolds in real time, with a "sender" and a "receiver", and that both share an attentive concentration on what is unfolding sonically. Christopher Small's concept of *musicking* was briefly mentioned in section 2.2., and in his book with the same title, Small writes in the *Prelude*:

> I have proposed this definition: *To music is to take part, in any capacity, in a musical performance, whether by performing, by listening, by rehearsing or practicing, by providing material for performance (what is called composing), or by dancing* (Small, 1998, p. 9)

Here Small aims to establish that all these activities belong to the same engagement or activity, which he gives the word *musicking.* My project in this chapter is not as broad as Small's, as it endeavors to argue that certain social and *intersubjective* qualities belong to a specific music and musical focus. However, they both share the aim of dissolving established roles or hierarchies within music. My main burden of proof in this endeavor is to demonstrate in which ways the particular kind of JI music I am describing enables a shared mode of listening, and how this is unique to JI music.

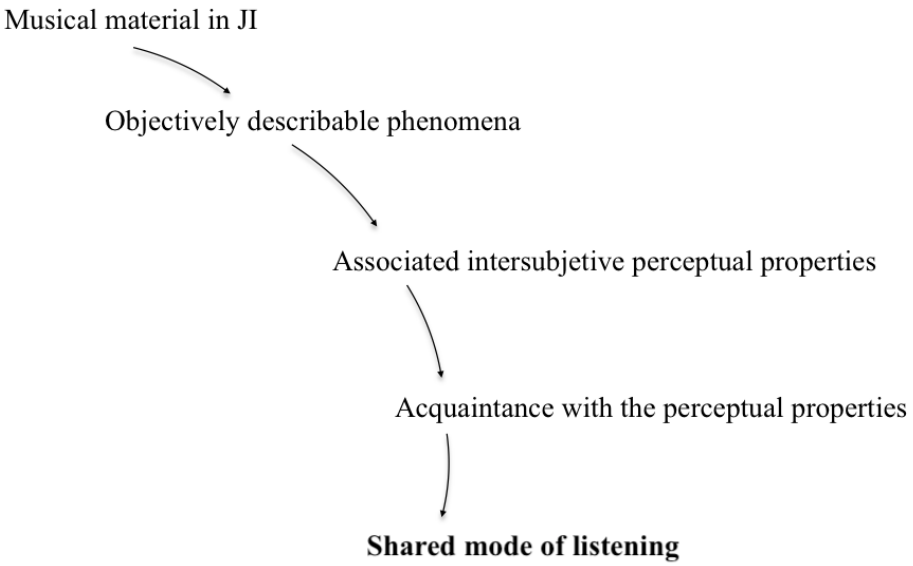
5.1. A shared mode of listening

When intonation is used as a flexible parameter in music, the sonic universe of tonal relations awakens. One becomes aware of the inherent acoustic actualities of simultaneously sounding tones. How these acoustic actualities and their theoretical counterparts relate to JI specifically has become evident through this thesis. With a sharpened sense and overview of the sound, each little micromovement, e.g. of the fingers stopping a string on the fingerboard of a string instrument, impacts the overall sound quality of the harmony and gives the performer real time information to employ in the act of tuning. The issues at stake in the process of tuning can be posed as questions: does the beating frequency increase or slow down by this slight sharpening of my note? Is the overall harmony stable (non-beating), and what is my

contribution to reaching/maintaining stability? Do I need to strengthen the volume or brighten the timbre, to support the collective effort of tuning? Through acquaintance with this material, tuning becomes an *internalized* practice, where the process and feedback of continuous listening and adjusting happens through an awareness that is not primarily bound to cognitive processes. The particular internalized *skill* of tuning is what enables the performer to focus on *listening*, opposed to merely reading the right frequency from a tuner application or other external means for rendering a note "in tune". The following sections focus on the specific *mode* of listening underlying this skill and how this mode of listening can be *shared* between performers and listeners. To this end, we will illuminate some properties of JI music that are sufficient to, however not necessarily exhaustive in, giving rise to a shared "listening space" – the main ones being the *objective*/*intersubjective* properties of JI, and the processes involved in tuning and in long durations of sound.

5.1.1. Objective/intersubjective properties of JI

As we have seen both in chapter 3 and 4, intonation of tones has certain properties such as presence or absence of beating, difference tones etc. – properties that can be called *objective*, since they are describable and measurable inside the physics/science of sound, and not merely in its phenomenology. However, since we are focusing on the *perceptual* and *experiential* facets of sound, i.e. as they appear to humans, it is more useful and exact to render these *intersubjective perceptual properties*. Building on the JI-specific findings of this research I will in the following take the term *JI perception* to mean *JI-related intersubjective perceptual properties*. The possibilities for describing, perceiving and adjusting JI sounds with accuracy *originates* in JI perception. While JI perception is in principle available to anyone (with a normal functioning sense of hearing), because of its intersubjective nature. This makes the listening situation *transparent*, and thus also *shared*. Evidently, we are here sketching an idealized situation where both audience and musicians are *acquainted* with these properties, and where they have a shared focus and attitude towards the sound. We can make a preliminary overview of these criteria, with arrows showing how they are connected as causes and effects (fig. 6):



The criteria discussed so far – the objectivity/intersubjectivity of the perceptual properties involved in JI, combined with acquaintance with them, are sufficient for giving rise to a shared listening space, since both musicians and listeners share a *similar* focus on the *same* sonic qualities. We will shortly discuss other arguments for this case. However, finishing this section about the objective/intersubjective properties of JI, we will have a look at some views on this matter in the writing of Alain Daniélou (also cited in section 3.1.). Daniélou was a proponent of just intonation and had strong opinions relating to these matters, which becomes evident in the following passage from his article *The Influence of Sound Phenomena on Human Consciousness*, where he discusses the phenomenal qualities of JI harmony – giving descriptive/associative terms to the comparison between the Pythagorean major third 81/64 and the harmonic, or 5-limit major third 5/4:

> [...] 81/64 is an active interval, brilliant, enterprising, glorious, intrepid, exalting; whereas the so-called harmonic major third corresponding to a frequency ratio of [...] 5/4 is a tender interval, affectionate, peaceful, calming, passive, relaxing (Daniélou, 1966 p. 25-26).

This associative language and endeavor of describing the phenomenological *qualities* of the intervals is relevant for our discussion about the intersubjectivity of JI perception.

Further, in discussing just versus tempered intervals, he argues for an inherent connection between our perception of hearing and rational intervals, with corresponding consequences regarding objectivity/intersubjectivity:

> The tempered intervals will moreover always remain very approximate because we apparently do not have an audio-mental apparatus which would permit us to analyze multiples of $12\sqrt{2}$ (Daniélou, 1966 p. 26).

Here, Daniélou is (implicitly) arguing that our *audio-mental apparatus* favors JI-intervals, and that the irrational intervals of 12-TET are interpreted or comprehended as approximations of these. Consequently, this is a claim aiming at establishing objective facts belonging to the human sense of hearing, and as such being in concord with our general line of argument in this chapter.

In this section we have discussed the objective and intersubjective perceptual properties belonging to JI, and argued that these, combined with acquaintance with JI and a certain listening focus, give rise to a shared mode of listening between musicians and listeners. In the following we will discuss other interconnected properties of JI, co-constituting this mode of listening.

5.1.2. Process, duration, equality

We will now turn to *durational* and *processual* aspects of JI-tuning, and how they contribute to the described shared mode of listening. In section 1.2. we characterized the music that is part of this research as a music that *favors sustained sound and/or repetitive elements*, and all the case studies are exemplifying these characteristics in various ways, depending on the musical material and the means for sound production. In the *Murmurations* and the various Ebow-setups that they are composed for, sustained notes are a part of the *teleology* of the setup, as Ebows make strings sound indefinitely. In *Svevning,* on the other hand, the repetitive plucks of combinations of guitar strings create long lasting sonic landscapes without the possibility of sustaining chords uninterruptedly. In the following I will take the description "sustained tones" to mean *the maintenance of a unitary harmonic landscape*, hence covering

both the repetitive plucks in pieces like *Svevning*, and the sustained harmonies in pieces akin to *Murmurations.*

By employing sustained tones, the focus on *process* becomes clear in different ways, with implications for the shared mode of listening we are discussing in this chapter. The performed tuning of a note is, as we have seen, itself a process. One approach to the process of tuning is using glissando – aiming for the designated note from below or above and gradually hearing how it "falls into tune" as one gets closer to the tuned state. Typically, when the right tuning is achieved, one can support the new found tuned state by increasing the volume of the produced note. While these approaches are instrument specific and most descriptive of instruments capable of sustaining long notes and changing the dynamic and timbre of them in real time, even a plucked guitar can accommodate the tuning within its own limitations - e.g. by timing a retuning to exact moments within the tonal decay of a pluck, or adjusting the dynamics and timbre of the plucks to bring forth harmonic details. Taken together, the implementation of tuning into music is a temporal process of *approaching* and *arriving* at a specific *tuned state*, where also the *untuned state* is an integral part of the searching involved in this process, and hence in this approach to music as a whole. Furthermore, the tuned state is not granted once it is found, it has to be *maintained*. Furthermore, in interplay, a tuned state takes every ensemble member's collective effort to be found and maintained, which demonstrates a certain *equality* involved in this kind of music making. Also the receptive audience member will be aware of this social element of equality and the resulting unfolding music, which can ultimately stimulate the audience member's feeling of themselves also being part of a shared experience. To sum up so far – the *mode of listening* is shared with the listener through the *process* and the *transparency* of the tuning situation, which is connected to the *intersubjectivity* of JI perception. The *acquainted* listener will have access to the same sonic information, and be subject to the same "yearning" to turn an untuned state into a tuned one.

At this point I want to clarify that in arguing for a shared mode of listening, many important aspects of the listening experience are not parts of this very line of argument. *Experiences* are bound to the whole of subjective states of mind, while what we are arguing for here is that

intersubjective perceptions give rise to a certain *mode of listening* – which is merely a point of departure from where subjective/personal experiences arise.

Another *processual* factor in this kind of music is integral to the often utilized elongated and gradually unfolding form. Since a recurring theme in this research is (inter)connections, and parts constituting wholes, we can say that while the *teleology* of my Ebow-setups produce sustained harmony as musical material (as expressed earlier in this section), the teleology of this material is to be situated in a corresponding sustained *form*. Regarding the mode of listening to this kind of music, the sustained form invites a real-time perceptual assimilation to, or acquisition of, the sound. By being in the sound for a long time, the listening itself changes – one becomes aware of different sonic elements and relates to the sound differently, as one *adapts* to it. And the collective partaking in this process, either in the role of actively producing the sound or in merely engaging with it as a listener, is constitutive of a shared mode of listening.

We will end the discussion of the role of duration in creating a shared mode of listening by referring to the Swedish JI composer, artis, mathematician and poet Catherine Christer Hennix (1948 -). She expresses related thoughts in an interview by journalist and writer Marcus Boon, when they are discussing sustained tones in the style of *drone*-music that Hennix creates:

> If a listener is just listening to the drone with no musicians present, eventually because of the plasticity of your brain you will start to hear it differently, you will start to hear more harmonics than you heard the first hour. Well, that means you have changed. Now you hear more than before. Just by yourself. Just by being patient and getting inside the sound. I felt that was the most extraordinary thing about this music, that it actually changed you from the inside in a miraculous way. You start to hear things that at first you didn't hear. I thought that was spectacular. (Boon, 2020)

We see from this quote that Hennix both addresses the way that long durational drone music *changes* you as a listener, and a quality of the *listening attitude* that the music demands or invites, namely that you have to be patient and get “inside the sound”. In other words, there is

an active dual-way engagement where the music changes you and you change the music, as perceived and experienced.

In conclusion, thus far – the mode of listening shared between musicians in interplay is transmitted to the listener through the *transparency* of the *intersubjective* and *perceptual* process of tuning, *and* through the impact of the *durational* processes on the listening experience.

5.1.3. Acoustics, dimensionality, ephemerality

In this last section of the chapter, we will discuss the remaining three elements that I consider important parts of the *shared* listening experience of the kind of JI music where sustained notes are integral - namely *acoustics*, *dimensionality* and *ephemerality*.

Firstly, the *acoustics* of the listening space is an important element of this music and its listening because the task of achieving and hearing the harmony in its tuned state will be clearer or blurrier depending on the room acoustics. A "dryer" room will be clearer in some sense, but a more reverberant room can also make the resonance of the sound become more alive in a way that does not blur the clarity of the tonal interactions. Especially relevant for this line of argument, the acoustics of the space is an element that can make a bridge between the audience and the performers because the space itself gets sonically "activated" in a way where one can feel as a part of the sonic room, or of the sound itself. This is closely related to listening as a process, but where processes are *temporal,* this experiential quality of listening is *spatial*, and the sound becomes a vehicle for experiencing spatiality. Whereas this aspect of listening is not unique to just intonation, *JI perception* is particularly sensitive to room acoustics and spatiality.

With the term *Dimensionality*, I mean the different perceptual dimensions of JI. The accentuated and aligning overtones, the periodic "grain" of the tonal interactions, the clarity and stability of the sound – taken together, all these are *dimensions* both of the perception and the total listening experience, dimensions that can be explored in the active attitude to listening, as well as the transformative effect of listening to sustained sound, described by Hennix. In directing their attention to these different dimensions, the listener can perceive the

sound either as a unity or as fragmented. The shared mode of listening thus arises when the listener becomes an actively listening *participant* in the unfolding music.

When JI music is realized by performers tuning in real time, the *ephemerality* of the tuned sounds is an element of JI music contributing to a shared mode of listening. As mentioned, a tuned state is to be *maintained*. Moreover, JI harmony is ephemeral or fragile, and maintaining it in its tuned state is a real-time endeavor guided by our ears, involving micro-processes of seeking, finding, maintaining, losing, regaining etc., the intended sound. Regarding the shared mode of listening – the ephemerality and fragility of the tuned states impacts the experience of listening both for musicians and listeners, where the sonic manifestation of and in the present appear salient and unique.

6 - Conclusions and ways ahead

In this text we have seen how the inherent *structural* and *perceptual* principles of JI create a foundation from which we can organize tones, each comprising the individual threads of a harmonic fabric, into a vivid and multi-dimensional music with consequences beyond its own realm. The goal for this text has been to systematize and analyze the key elements of a personal music making where JI plays a key role, and more specifically, where JI comprise a perceptual praxis. This last and concluding chapter will be brief and tripart. First, we will sum up the main points of this research in relation to the research questions. Second, we will look at concluding elements. Last, we will look at some possible directions for future research, building upon the findings of this thesis.

As we have seen throughout this text, the answers that this research has given to research questions 1 and 2 reveals a close codependency between the topics that the two questions bring up. The ways in which JI can serve as an organizing principle in the kind of music that has been the main focus in this thesis, namely in music involving real-time JI tuning, is *conditioned* by *tunability*, and hence by the relation between structure and perception in JI. The way we have used the term *structure* here, it covers the aspects of JI that can be categorized into theoretically structured knowledge, such as rational number relations (ratios) and harmonic fusion – at the same time retaining a sense of the term as belonging to the to the sound itself (*objectively*) and/or to our perception of it (*intersubjectively*). The *relations*

between structure and perception of JI is demonstrated through how theoretical concepts and sonic perceptions *correlate with each other*. There is an elemental philosophical aspect at play here regarding the order or priority of *analysis* and the *object of analysis*. We would not analyze or conceptualize JI sound in terms of numbers, fusion etc. if we did not already have a particular initial *sound* which caught our interest. Starting with the sound and its perceptual effects, we subsequently proceed to form concepts through research, be it empirical, phenomenological, or rooted in other research methodologies. Hence, our most distilled answer to research question 2 is that structure and perception of JI are two aspects of one thing, and that their relations are constantly and continuously enriched through engagement with JI. Looking at research question 1 also independently from the bold conditions of tunability and perception/structure, we have seen examples of using the different facets of JI in composition, where different prime limits, commas, and modulations are some of the key aspects at play in organizing JI music. Regarding research question 3, we have seen how JI can be realized with guitar(s), exemplified in *Svevning*, *Point/Wave*, *Murmurations* and *Six Moving Guitars*, and the corresponding differences in approach to composition and the aspect of real-time tuning.

The concluding elements of this thesis both comprise these answers to the research questions, and the establishing of the case for JI involving a *shared mode of listening* between musicians and audience in situations where this kind of music is realized. This mode of listening is composed of the *intersubjectivity* of JI perception, as well as its ephemeral, dimensional, spatial, and *processual/transparent* elements. Through these characteristics we have laid a conceptual *foundation* for what this shared mode of listening can contain, in terms of non-hierarchical social structures within a musical praxis with JI. A foundation from which further research into its deeper reality can be conducted. This leads us into the last paragraph of this chapter and thesis, pondering on possible future research taking the present findings as foundations.

A possible next research project can be about the connections of ethical/social and experiential/perceptual aspects of JI music making. Methodically, it can focus on case studies of *collective* playing situations, it can make use of discussions or interviews with peers on the

relevant topics, and it can employ comparative studies between JI music and other kinds of music; or other kinds of human expressions more broadly. The research question might be: *In which ways does just intonation provide conditions for a non-hierarchical music making?* This question would take the points about *a shared mode of listening* as a point of departure in researching how both composed and improvised JI music can be structured in egalitarian or non-hierarchical ways, and further investigate the social, ethical, aesthetic and phenomenological implications of the this outlined shared mode of listening, and more generally, of JI *musicking*.

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