Kurs: **DA3005 Självständigt arbete 30 hp**  
2022  
Konstnärlig masterexamen i musik, elektroakustisk komposition 120 hp  
Institutionen för komposition, dirigering och musikteori  

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**Heating the reeds**

Just intonation and learning the shō

Skriftlig reflektion inom självständigt arbete

Till dokumentationen hör även följande inspelningar och partitur:  
*Hypothermia for bass drum; Stycke för cembalo och elektronik; Breathing, bowing; Solo #1*
Henrik Frisk, for five years of experimentation and discussion;
Ludvig Elblaus, for engaging in my work and pushing me in all the right directions;
Ishikawa Ko-sama, for accepting me as a student and giving me nothing but encouragement;
Marcus Pal, for introducing me to harmonic sound;
Kristofer Svensson, for the seemingly never-ending discussions;
Giovanni Onorato, for finding a common ground and a wonderful friendship;
Viktor Sandström, for the technical and artistic support, as well as being such a good friend;
Arvid Kraft, for all the engaging and critical discussions;
Ivar Koij, Johann Fritsche and Louise Agnani, for doing such a wonderful job performing my music;
Vilhelm Bromander, Johan Arrias and Gard Nergaard, for agreeing to play with such a newbie;
Kim Hedås, Mattias Petersson, Mattias Sköld, Christofer Elgh, Per Mårtensson, Åsa Stjerna, Jenny Sunesson, Gerhard Eckel and Bill Brunson, for all the lessons both inside and outside of the classroom;
Selma Morshed, for widening my perspectives, giving me both support and the right amount of critique;
Henrik, Stina, David and Sofia Hällsten, for all the love and support;

Thank you all. This work would not have been possible without you.
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1 Introduction

My compositional practice has previously been focused primarily on electronic sound. By utilising different synthesis and spatialisation techniques I have in numerous pieces explored how electronic sound can behave like acoustic sound, experimenting with the electronic sound’s perceived sound source. Examples of this can be found in multi-channel fixed media pieces such as *The Aimless Blade of Science* (2017) and *Walls of Amber* (2018), and I elaborated on this in my bachelor’s thesis titled *Rum och rundgång: Ett försök att kartlägga ljudande upplevelser* (2019). The ways in which I think about electronic sound, and ultimately the ways in which I listen to electronic sound, have been shaped by composer Denis Smalley’s definition of the term *spectromorphology*, presented in *Spectromorphology: explaining sound-shapes* (1997), as well as philosopher Casey O’Callaghan’s proposed *event view* regarding the ontology of sound (O’Callaghan 2009).

In my master’s project I wanted to explore ways in which electronic sound can relate not only to acoustic sound, but to acoustic instruments. This has led me to compose four pieces: *Hypothermia for bass drum* (2020) for gran cassa and electronics; *Stycke för cembalo och elektronik* (2021) for harpsichord and electronics; *Breathing, bowing* (2022a) for viola da gamba and electronics; and *Solo #1* (2022b) for shō and unfiltered sawtooth waves. In these four pieces, I have explored different ways for the electronics to relate to and interact with the respective acoustic instruments. A consequence of this is that the performance of all of these pieces, except for *Solo #1* which I performed myself, have involved other musicians. Thusly, these pieces have not only been ventures into new aesthetic and technological areas, but they have also shaped my outlook on composition and the relationship between composer and musician. This will be explained thoroughly in the Section 4: *Pieces*, as well as in Section 5: *Formulating a practice*.

There are two central themes in this project. The first one is an interest in various tuning styles and intonation patterns, with an emphasis on *just intonation* and a listening-based intonation practice. The second one is the Japanese mouth-organ *shō*, used primarily in the ensemble performing the Japanese court music *gagaku*. This instrument and its tradition has played a big part in shaping the aesthetic foundation for the works I will present in this text, and I am currently learning to play the shō. This has in turn not only shaped my artistic practice aesthetically, but also my identity as both composer and musician.

Before discussing the pieces, I will give a brief introduction to both subjects in Sections 2 and 3. After that, I will present the pieces in question in Section 4, followed by a discussion in Section 5. Finally, I will conclude this text with some finishing remarks in Section 6.
2 Gagaku

Gagaku “signifies the whole body of classical music and dance performed by the musicians of the Kunaichō Shikibushoku Gakubu (Music Department of the Board of Ceremonies of the Imperial Household Agency, Tokyo)” (Nelson 2017a, p. 36). It is the music of the Japanese court, and the music can be traced back to Japan importing cultural elements from China, Korea and India during the Nara period (710-794 A.D) (ibid., p. 38). Additionally, gagaku contains elements of the traditional Japanese music that was performed before the Nara period (Togi et al. 1971, p. 122).

Two of the categories of gagaku are *tōgaku* (with Chinese roots) and *komagaku* (with Korean roots) (Nelson 2017a, p. 36). My primary interest in gagaku has been in the *tōgaku* tradition.

The ensemble playing *tōgaku* music consists of (seen in Figure 1 from the top-left): the *ryūteki*, a transverse flute; the *hichiriki*, a double-reed wind instrument similar to the *duduk* or western oboe; the *shō*, a free-reed mouth-organ; the *koto*, a thirteen-stringed zither; the *biwa*, a four-stringed lute; the *shōkō*, a small gong; *taiko*, a large drum of about 55 cm in diameter; and the *kakko*, a two-headed barrel drum (Kapuściński and Rose 2020). The hichiriki and ryūteki are the main melodic instruments.

![Figure 1: The gagaku ensemble.](http://gagaku.stanford.edu/en/)
Discussing gagaku in depth and explaining the differences between the different categories of gagaku is beyond the scope of this text. However, I will here give a more in-depth description of the shō instrument and its traditional performance practice, which has been influential in my own artistic practice, both in terms of aesthetics and musical form as well as in developing my practice as a musician.

2.1 Shō

The shō (see Figure 2) has seventeen bamboo pipes, each pipe having a small metal free reed producing the sound (Ishikawa n.d.). It was developed in Japan after its Chinese cousin sheng is said to have been gifted to the Japanese court around the eighth century (Missin 2006). Although there has been several varieties of the shō throughout Japanese history, with different numbers of pipes (Doktorski 2000) and consequently different ranges, the instrument is in its modern form a very limited instrument with a range of roughly one and a half octaves. This contrasts the sheng, which in its modern form has 37 pipes with a range of three octaves (Missin 2006).¹ I am currently being taught to play the shō by my teacher Ishikawa Ko.²

In short, in traditional tōgaku music the shō plays one of eleven aitake (see Figure 3). These would in western music theory be considered cluster chords. On top of the eleven aitake, there is a system for moving between the aitake in very specific patterns, called the te-utsuri. The direction of movement makes for a different te-utsuri, i.e. moving from aitake A to aitake B is sometimes a different pattern than moving from aitake B to

¹See the Appendix for one video of musician Wu Wei demonstrating the sheng, as well as one video of musician Naomi Sato demonstrating the shō.
aitake A (Garfias 1975, p. 47). Musicologist Robert Garfias concludes that “[t]he effect of the patterns is to give a distinct character to the connection of any two aitake” (ibid., p. 47). There are two key things that fascinates me about this. Firstly, that it makes for a musical system where harmony and rhythm are not separated but one and the same – the idea of an aitake also contains rules guiding how that aitake is played rhythmically. Secondly, it is a system of states and transitions. Each aitake is a state, and each te-utsuri is a transition.

The shō is tuned in pythagorean tuning, which is derived from stacking pure fifths. I will discuss this more in depth in Section 3, but it is important to note that one of the consequences of pythagorean tuning is that the circle of fifth cannot be closed, which generates out-of-tune variants of some intervals, most notably the wolf fifth. To avoid these intervals, the shō cannot play a chromatic scale and the notes F♯, B♭/A♯ and E♭/D♯ are omitted (Ishikawa n.d.).

When playing the shō, the musician both inhales and exhales into the mouthpiece and covers the holes of the pipes to be sounded. When the musician exhales, warm air passes through the instrument from the musician’s breath, and when the musician inhales cold air passes through the instrument from outside the instrument. Because of this, condensation builds up on the reeds, causing the instrument to go out of tune. To dry out the condensation the instrument has to be heated before playing, traditionally by burning coal. My teacher Ishikawa Ko has instructed me to heat the instrument with a small electric heater for approximately 15 minutes before playing, and usually the instrument can be played for 20 minutes before the musician has to heat the instrument again. Because of this, solo pieces for shō tends to not be longer than 20 minutes.
3 Tuning and intonation

In the article *Teaching a Melodic/Harmonic Awareness of Intonation* (1992), viola player Michael Kimber explains how he approaches teaching students what he calls “good intonation”, which “is not rigid but flexible and [...] requires continuous listening and adjusting” (ibid., p. 59). The system that Kimber proposes seems to be the system commonly utilized for string players, namely separating melodic intonation, meant to emphasize melody, from harmonic intonation, meant to give primarily thirds and sixths a sonorous quality in the context of Western harmony. However, the discrepancy between melodic and harmonic intonation is usually not reflected in written scores. Rather, the musician is expected to adapt their intonation in relation to the context of the piece.

The lack of indication of precise intonation seems to be common in many musics around the world, both musics that are orally transmitted and musics that are written down. In reflecting on intonation patterns in the music tradition *maqam*, violin player Sami Abu Shumays discusses the regional aspects of intonation:

The *maqam* tradition is practiced in one form or another from North Africa, through Turkey and the Levant, through Iran and Central Asia, all the way into western China. In Syria, the E-half-flat that is the third note of *maqam rast* (a note somewhere in between e-flat and e-natural) is slightly higher than the E-half-flat in *maqam rast* as played in Egypt, yet a phrase in *maqam rast* is unmistakable as such, and a Syrian will recognize an Egyptian playing *rast*, even if he also recognizes it as the Egyptian version and not his own. The differences in intonation and ornamentation are even more pronounced—while still retaining the *maqam* identity—if we compare Arabic melodies with Turkish and Greek Rebetika melodies. (Shumays 2009, original emphasis)

Both these examples indicate that the way the respective musical traditions and their intonation patterns are usually described (twelve-tone equal temperament for Western string players; twenty-four tone equal temperament for maqam players) is an over-simplification. There is more nuance to the way the pitches in both musical traditions are performed.

One tradition of intonation that demands that precise intonation is indicated in the written scores, and thus gives the composer greater control of the precise pitches that the instruments are producing, is just intonation. Just intonation is of great importance to my musical practice, however not with the goal of playing otherwise tempered intervals more in tune. Rather, I aim to explore the specificities of both the pitch heights of just intervals and the arising auditory phenomena, as well as how the act of tuning just intervals differs from other intonation practices. Furthermore, one of the most important characteristics of just intonation is the fact that the intervals are tuned in accordance to the sound itself, which can be applied to other contexts of intonation.
3.1 A comment on notation and terminology

The terminology used among scholars and composers when speaking of phenomenon related to rationally tuned intervals, i.e. just intonation, is not uniform. Late composer Ben Johnston differentiated between *just intonation* and *extended just intonation*, stating that “[t]he term *just intonation* connotes to most people either a very specialized concern with Renaissance and medieval choral music or an equally specialized concern with pre-piano keyboard music” (Johnston 1967/2010, p. 111, original emphasis), in practice 5-limit just intonation. Extended just intonation, however, for Johnston “implies a pitch system in which intervals deriving from the relatively unfamiliar seventh partial of the harmonic series (in ratio terms, 7/4) and/or higher partials—the eleventh, thirteenth, seventeenth, and so on—are used together with the more familiar intervals that form the basis of conventional triadic tuning” (Gilmore 2010, p. xv).

Composer Catherine Lamb, on the other hand, uses the term *rational intonation* instead of just intonation (Klingenschmitt 2022, 7’08”). Finally, in *Fundamental Principles of Just Intonation and Microtonal Composition*, composers Marc Sabat and Thomas Nicholson designates the term *microtonal* to suggest intervals smaller than a whole tone (Nicholson and Sabat 2018, p. 2), even if they can be expressed as whole-number ratios.\(^3\)

In this text, I am using the term *just intonation* to encompass all intervals that can be expressed as whole-number ratios in a rather free way. I acknowledge that this can be problematic, as very complex just intonation intervals in this definition might be not tunable by ear, as is one of the prerequisites for just intonation as defined by composer and music theorist Kristofer Svensson (2020). As the reader will see, however, although some of the intervals I use in my compositional practice are complex, they are all derived from each other using simple whole-number ratios in a given piece, i.e can be easily expressed as a matrix as explained below. The sole exception to this is the ratio 11:10 used in *Stycke för cembalo och elektronik*.

Additionally, as with the written scores, I am using two ways to designate pitch relations:

1. The Helmholtz-Ellis Just Intonation (HEJI) system.\(^4\)

2. Frequency ratios written with a colon in the format a:b, i.e 3:2. This can also be expanded

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\(^{3}\)Outside of the just intonation discourse the word microtonal sometimes refers to any interval that differs from twelve-tone equal temperament (Griffiths, Lindley, and Zannos 2001). However, this would mean that for example any string player that adjusts a major third (in the way described by Michael Kimber), or any adjustments of intonation for that matter, would give rise to a microtonal interval, which illustrates how the term can be problematic when not precisely defined.

\(^{4}\)https://marsbat.space/pdfs/HEJI2_legend+series.pdf
as a numery nexus: the chord Cₐ - Gₐ - B♭ₐ, for example, can be written as 4:6:7, since Cₐ - Gₐ has the relationship 2:3 (4:6) and Gₐ - B♭ₐ has the relationship 4:7.⁶

In the case of two sound sources playing together, I write the chord in either HEJI or as a numery nexus, with a box around the notes played by one of the instruments.

Finally, one common way of representing a given just intonation tuning is by presenting it as a grid, where each axis corresponds to one interval. By doing so, one can trace the origin of each interval in the tuning, and clearly see that for example the interval 15:8 is the resulting of multiplying a pure fifth (3:2) with a major third (5:4). In Figure 4 the x-axis represents a pure fifth (3:2) and the y-axis represents a major third (5:4). Please note that in all the graphs representing a just intonation tuning in this text all intervals have been transposed to fit within the same octave as the root note. This is in line with late composer Harry Partch’s theory of monophony, which essentially is equivalent to contemporary just intonation (see Partch 1974).

Figure 4: A grid representing a 5-limit just intonation tuning, showing how the ratio 15:8 relates to 1:1.

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⁵ If one number [of a ratio] is fixed, it becomes a numery nexus (i.e. ‘anchor point’). Ratios with a given numery nexus are related by that nexus - they have something in common” (Serotsky 2004). A numery nexus is simply a way of expressing any number of intervals that share the same denominator, often times used to express chords with more notes than two. As with a lot of the just intonation discourse, the term numery nexus originates from Harry Partch’s book *Genesis Of A Music* (1974).

⁶ Please note that frequency ratios are usually expressed as the value to multiply the tonal centres frequency with, i.e the interval Cₐ - Gₐ is expressed as 3:2 because the frequency of the note Cₐ is multiplied with 3:2 to reach the frequency of Gₐ, even though the first number 3 represents the second note Gₐ and vice versa. When expressing a chord as a numery nexus, however, the order is usually reversed.
3.2 Just intonation

One definition of just intonation can be found in the previously mentioned text *Fundamental Principles of Just Intonation and Microtonal Composition* by Marc Sabat and Thomas Nicholson. In the introduction of the text, Sabat and Nicholson state that just intonation “describes a particular way of playing ‘in tune’ – namely, of tuning musical intervals as small number frequency ratios to evoke a distinctive periodic resonance.” (Nicholson and Sabat 2018, p. 2). If two notes are tuned to just intonation, “some of their respective partials come into alignment” (ibid., p. 2), and depending on the interval and register this gives the composite sound a resting and beatless quality. This phenomenon is often described as *harmonic fusion*, where the two sounds fuse into the harmonic series of a perceived fundamental, known as the *periodicity pitch* (ibid., p. 2). When tuning in just intonation, it is the “distinctive periodic resonance[s]” (ibid., p. 2) of the respective just intervals that the musician listens for, which in many cases are the arising *combination tones* and in the case of most tunable just intervals the lack of *beating*.

In the book *Genesis Of A Music* (1974) Harry Partch defined the language of ratios (Partch 1974, p. 76). The *ratio* describes the relationship between two frequencies, and gives us a clue of their position in relation to the periodicity pitch: the frequencies 500 Hz and 300 Hz, for example, has the greatest common denominator 100.

\[
\text{GCD}(500, 300) = 100 \\
\frac{500}{100} = 5 \\
\frac{300}{100} = 3
\]

This gives us the ratio 5:3 to explain the interval between frequencies 500 Hz and 300 Hz, meaning that:

\[
300 \times \frac{5}{3} = 500
\]

We infer from this knowledge that the frequency 500 Hz is the fifth partial of the harmonic series of the periodicity pitch 100 Hz, and likewise the frequency 300 Hz is the third partial of the same harmonic series. The size of this interval can be expressed in *cents*, where one cent signifies 1/1200 of an octave. In the case of the interval 5:3 it has a cent size of about 884 cents, 16 cents lower than the Twelve-Tone Equal Temperament (12TET) major sixth. This way of explaining just intervals also brings to light Nicholson and Sabat’s statement about how, for a just interval, “some of their respective partials come into alignment” (Nicholson and Sabat 2018, p. 2). On top of being the fifth and third partial of the periodicity pitch 100 Hz respectively, the overtone series of the two
pitches in the above example coincide: the fifth partial of 300 Hz is the same frequency as the third partial of 500 Hz \((300 \times 5 = 1500 = 500 \times 3)\).

It is my belief that the practice of just intonation can be looked at and analyzed by considering two things: the distinctive qualities of just intervals, meaning how justly tuned intervals behave, including ways to categorize them, and the distinctive qualities of just intonation, meaning the practice of actually intonating these intervals.

### 3.3 Distinctive qualities of just intervals

Arguably, Harry Partch’s main contributions to the just intonation discourse of the 20th century was “the language of ratios” and the theory of prime limits. The prime limit is simply the highest prime factor of a ratio: the ratio 5:4 is a 5-limit interval due to the prime number 5 being the highest prime factor of the ratio. Similarly, the ratio 25:24 is also a 5-limit interval, for the same reason. The ratio 21:16, however, is a 7-limit interval, due to the prime number 7 being the highest prime factor of the ratio.

In the text *John Cage and the Theory of Harmony* (1983/2019), James Tenney expanded upon the idea of prime limits by defining the term harmonic space. In explaining harmonic space, Tenney writes:

> The phenomenon of “octave-equivalence,” [...] is just one of several specifically harmonic relations between pitches—i.e., relations other than merely “higher” or “lower.” This suggests that the single acoustical variable, frequency, must give rise to more than one dimension in sound-space—that the “space” of pitch perception is itself multidimensional. This multidimensional space of pitch-perception will be called harmonic space. (ibid., p. 294, original emphasis)

What Tenney is suggesting is that our perception of octave-equivalence is simply one dimension that stems from multiplying and dividing frequencies with the prime number 2. Similarly, multiplying and dividing frequencies with other prime numbers give rise to additional dimensions. For example, “the harmonic space implied by a ‘Pythagorean’ scale, based exclusively on fifths \((3/2)\), fourths \((4/3)\), and octaves \((2/1)\), is two-dimensional, since the frequency ratios defining its constituent intervals involve only powers of 2 and 3” (ibid., p. 295).

One musical example to explain harmonic space is La Monte Young’s *The Well-Tuned Piano* (1987), where Young tunes the piano in just intervals that avoids the prime limit five (Gann 1993, p. 136). In that case, Young is using three-dimensional harmonic space: the first dimension is derived from the prime number 2, the second from the prime number 3, and the third from the prime number 7. See Figure 5 for a two-dimensional grid explaining the tuning of the piece, and
note that although the harmonic space is three-dimensional, the idea of octave-equivalence is so ubiquitous that it can be inferred.

\[
\times \frac{3}{2}
\]

\[
\begin{array}{cccc}
49 & 147 & 441 & 1323 \\
32 & 128 & 256 & 1024 \\
B & F\# & C\# & G\#
\end{array}
\]

\[
\times \frac{7}{4}
\]

\[
\begin{array}{cccc}
7 & 21 & 63 & 189 & 567 \\
4 & 16 & 32 & 128 & 512 \\
C & G & D & A & E
\end{array}
\]

\[
\begin{array}{cccc}
1 & 3 & 9 \\
1 & 2 & 8 \\
E_b & B_b & F
\end{array}
\]

Figure 5: A two-dimensional grid explaining the tuning of The Well-Tuned Piano. Taken from Gann 1993, p. 135.

As well of being a powerful conceptual tool for navigating just intervals, by creating personal relationships with various just intervals I have found that the different dimensions in harmonic space contain certain aesthetic qualities. Although arguably subjective, I would describe five-limit intervals as calm and bright and seven-limit intervals as dark and mellow. This could be simply because my auditory system relates these intervals to their 12TET counterparts and therefore reacts to how for example the seven-limit minor third 7:6 is 33 cents lower than the 12TET minor third, but the theory of harmonic space that Tenney is proposing could be another a way of explaining this phenomenon. Even before learning of harmonic space, I have tried in my compositional practice to limit myself to specific dimensions of harmonic space, like in Young’s “The Well-Tuned Piano”. The ways in which I have done so will be discussed further later in this text.

### 3.4 Distinctive qualities of just intonation

As Kristofer Svensson points out, the act of tuning just intervals is different than that of tuning other intervals. Rather than producing intervals that are learned by “cultural learning and repeated exposure” (Svensson 2020), tuning just intervals demands of the musician to “tune pitches by ear into stable, resting composite periodic resonances” (ibid., original emphasis). According to Svensson,
when tuning to other intonation systems than just intonation the result is measured against a cultural understanding of the desired pitch-height by means of the musicians memory or electronic devices – as in the previous examples of Western string players and maqam musicians. When tuning to just intonation, the desired pitch-height exists within the sound. In an episode of Margot George’s podcast Unknown Language, Svensson elaborates on this while discussing how intonation relates to their own Buddhist practice:

[W]here are these intervals? Are they in the world? Are they in me? [...] attuning ourselves to these ratios is really being empty. Emptying ourselves of ourselves. We’re literally just tuning to these ratios. [...] It also relates to the fact that these pitches are [...] not socially constructed. [...] they appear when I empty myself and I go into a relationship with sound. Then these intervals appear. It’s not like I am approximating pitches that I have been taught because I belong a certain culture. [...] When I tune my voice and my body to these sounds, and empty myself, I enter into pitch relations that are not socially constructed. (George 2021, 49’16”)

When entering a frequency ratio in computer software, the user is immediately presented with the ideal size of that specific frequency ratio, and I would argue that the act of finding the correct pitch-height within the sound, which seems to be the crucial difference between just intonation and other tuning systems, is lost when doing this. Not to say that there’s anything wrong with computer generated just intonation – generating notes that cannot be tuned by ear is one of the most interesting branches of tuning theory. When speaking of using the Rayna synthesizer, which is a digital synthesizer that features very precise pitch control, La Monte Young mentions that it could produce intervals that “nobody had ever been able to hear [...] before” (Young 1996/2018, p. 71), referring to the synthesizer being able to produce just intervals that are not tunable by ear. That, however, relates to the distinct qualities of just intervals, not the act of tuning just intervals.

My own relation to composition using just intervals has been primarily that of generating notes using the computer, and in 2020 I wrote a program in SuperCollider\(^8\) titled Just Intonation Trainer\(^9\). The position that just intervals are not socially constructed is arguably one of the more controversial parts of Svensson’s theoretical framework. This discussion is beyond the scope of this text, but the remark still deserves a comment. I think that Svensson’s point is that although there certainly exists social constructions where just intervals are desirable, i.e. institutions or musical styles that inform the musician of correct intonation, the genesis of the intervals are not socially constructed. The most widely used just intervals can easily be found in the lower part of the harmonic series, and after learning to hear partials in a harmonic spectrum one can clearly hear a just major third, perfect fifth, harmonic seventh and so forth in many sustained sounds. If one learns to hear, the intervals appear, and although slight variations of the sizes of the intervals are present due to the varying degrees of harmonicity of different sound sources, it still affords a way of intonation where the musician listens for harmonic fusion and “stable, resting composite periodic resonances” (Svensson 2020), which is what characterises just intonation. However, this position should not be confused with a naturalistic one: there is nothing that makes just intervals better than other intervals just because they can be found in the harmonic series. For an elaboration on Svensson’s position concerning social constructionism and how it relates to tuning, see their text Varieties of Just Intonation (2020).

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\(^{8}\)SuperCollider is “...a platform for audio synthesis and algorithmic composition, used by musicians, artists and researchers working with sound.” https://supercollider.github.io/

\(^{9}\)https://github.com/mattiashallsten/ji-trainer
with the purpose of practicing actually intonating the intervals myself. I used this program to practice playing just intervals on an acoustic guitar, using an Ebow\footnote{https://ebow.com/} and a bottle-neck slide. Although this has yet to make its way into my wider artistic practice, I still felt my embodied relationship with several just intervals becoming stronger. As such, while this is not a developed component of the pieces presented in this text, it is surfacing as a strong element in my practice and will play a major role when approaching my own performance practice and role as performing composer in my future work.

### 3.5 Tuning in gagaku

In gagaku music, as previously mentioned, the shō is tuned in pythagorean tuning. Since pythagorean tuning simply means to stack perfect fifths, the tuning of the shō can be expressed as a circle of fifths, as can be seen in Figure 6. The circle of fifth also makes it clear why the notes Fś, B♭ (called B♮ in Figure 6) and D♯ are omitted. With James Tenney’s terminology, this means that the shō defines a two-dimensional harmonic space. Using the note E as the root note (in just intonation terminology the ratio 1:1), frequency ratios can be derived from Figure 6 expressing the tuning of the shō, as can be seen in Figure 7.

Since the hichiriki and ryuteki are more flexible in pitch and use various ornaments such as glissando, one could say that the shō defines a harmonic space that the hichiriki and ryuteki expand. A gagaku recital usually starts with a short prelude called netori, meant to establish the musical mode of the performance (Togi et al. 1971, p. 71). When for example listening to the ensemble...
Tokyo Gakuso’s recording of *Hyojo no netori* (netori for the *hyojo* mode\(^\text{11}\)), found on the CD *Gagaku & Beyond* (2000), one hears the first few notes played by the shō, which is later joined by both the hichiriki and ryuteki, and later the full ensemble.

I have found the theory of harmonic space to be a way to relate the gagaku tradition to my own artistic practice, both as a composer and as a musician. As can be heard in *Solo #1* (2022b), which will be discussed in more detail in Section 4.4, on certain chords the pythagorean foundation that the shō defines is expanded to other dimensions of the harmonic space with the use of sawtooth waves playing seven-limit just intervals. On other chords the sawtooth waves are tuned in such a way that makes it sound as though the shō is producing seven-limit just intonation intervals while that the sawtooth waves are producing pythagorean intervals, reversing this relationship.

However, although harmonic space has proven to be a powerful model for exploring the intonation of gagaku, I think that it is dangerous to assume that all cultures have just intonation as the foundation for their respective tuning tradition, and I want to make it clear that this is not the intention of this discussion. I have far to many times in the past fallen into the trap to assume that humans naturally gravitate towards just intonation, and I have realized after learning about very precise tuning traditions that falls outside the realm of intonation in accordance to the overtone series (maqam being an example already mentioned in this text) that the de facto standard in fact is *not* to play in just intonation. My aim with discussing the intonation of gagaku music is thus not to point out any tendencies towards just intonation (apart from the obvious pythagorean tuning of

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\(^{11}\) The *hypojo* mode is, in Western terminology, essentially an E dorian scale; see Malm 1959, p. 101.
the shō). It is rather to, as stated above, relate the gagaku tradition to my own artistic practice.
4 Pieces

4.1 Hypothermia for bass drum

Title: Hypothermia for bass drum  
Duration: 15’52”  
Instrumentation: Gran cassa, Loudspeaker, Microphones, SuperCollider  
Premiere: 2021-04-14 by Ivar Koij and Mattias Hållsten  
Venue of premiere: Lilla Salen, KMH

4.1.1 Instrumentation and feedback

The setup for *Hypothermia for bass drum* consists of a gran cassa, a full-range loudspeaker and two microphones. The loudspeaker is placed as close to the center of the resonating skin as possible, and the two microphones are placed on different points close to the batter skin. The sound of the gran cassa, picked up by the microphones, is fed through a computer running custom signal processing software written in SuperCollider. The two signals are mixed and sent back into the loudspeaker, completing a feedback loop.

The processing used for the two microphone signals is a low-pass filter, a high-pass filter and a compressor, to keep the resulting feedback in control. While performing the piece, the person controlling the electronics can vary the mix between the two microphone signals as well as the high-pass and low-pass filter cutoffs respectively with the use of a MIDI controller, in order to shape the different timbres and behaviours emerging from the feedback.

The reason for utilizing feedback is to inherently relate the resulting timbre to the physical properties of the gran cassa. For example, the pitch of the feedback is affected by the shape and size of the drum as well as the tension of the drum heads. The gran cassa filters the feedback loop with the intention of the resulting sound to appear as coming from the drum, not from the computer.

4.1.2 Tuning

On top of using the setup in *Hypothermia for bass drum* to generate feedback, low sine waves are also played back from the speaker placed behind the drum. The sine waves are tuned in simple rational intervals in relation to the pitch of the feedback, which in many instances results in harmonic fusion. However, since the sine waves are both played back through the drum and picked up by the microphones, therefore interacting with the feedback, this harmonic fusion is exaggerated and acts even more as a way of shaping timbre – the function of frequency becomes timbre, not pitch.
The root note of the sine waves is adjusted in accordance to the pitch of the feedback, simultaneously controlling the pitch of all the sine waves while still keeping their internal relationships intact. But although the sine waves are tuned in rational intervals in relation to each other, when performing *Hypothermia for bass drum* I approach these fine adjustments in a rather intuitive way. The tuning of the pitches is done in accordance to the sound of the feedback system, which is not at all as predictable as a harmonic overtone series. Rather than adhering to a strict just intonation system, the tuning of the low sine waves is specific to their context, namely the feedback system they are projected into. Although this intuitive approach might sometimes stray away from just intonation, the intonation of the pitches is still derived from the sounding result, a characteristic it shares with just intonation.

The low sine waves are brought in and out by controlling their respective amplitudes in SuperCollider using the MIDI controller, and as they are tuned in real-time the timbre of the feedback is changed, as the sine waves are either disturbing the feedback by being out of tune with it or exaggerating its timbral qualities by being in tune with it. For a graph representing the signal flow of the setup, see Figure 8.

![Figure 8: The signal flow of Hypothermia for bass drum.](image)

### 4.1.3 Musical form

In works prior to *Hypothermia for bass drum*, I have worked extensively with the idea of musical states rather than linear progressions, most notably in *Walls of Amber* (2018) where the form was defined technically as chunks of SuperCollider code generating material of varying degrees of determinism, played for set durations of time – the chunks were the *states* of the piece. Although *Walls of Amber* has an overarching musical form that presents a linear progression, the individual parts of the piece are not organized in musical phrases, but rather a set of pitches and parameters that can be combined to create chords and emerging melodies. Additionally, this method of working serves as a way to structure the material both in terms of the sounding result as well as in the actual process of composition.

In *Hypothermia for bass drum*, as can be noted in the score, the form is constructed by defin-
ing ten states, represented in the score by numbered boxes, during which the material is more or less still, and transitions to move between the ten states, similarly to Walls of Amber. However, in Hypothermia for bass drum, this idea of musical form was largely inspired by the system of aitake and te-utsuri used in traditional shō playing, a discussed in Section 2.1 – the states represent the aitake, and the transitions represent the te-utsuri. The states of Hypothermia for bass drum allow for some degree of improvisation, where the electronics performer may explore the current timbre by adjusting certain parameters and fine-tuning the amount of feedback. The transitions of Hypothermia for bass drum, however, are largely pre-determined, both in order to retain the musical gestures discussed in Section 4.1.4 as well as be able to control the development of the timbre: the nature and timbre of the feedback is affected not only by the amount of feedback, but also the temporal development of the different parameters. For example, if the second microphone is introduced while the first microphone is creating feedback, the resultant timbre is many times different from when the first microphone is introduced while the second is creating feedback.

4.1.4 Musical gestures

When performing the piece, two musicians are on stage: one percussion player standing next to the gran cassa and an electronics player sitting at table with a laptop and MIDI controller. The two players are positioned in a V-like formation, facing each other, as a duo. There are two distinct kinds of musical gestures that the percussion player is performing: striking and pressing. The strikes are notated with arrow heads, and the presses are notated as regular notes, as can be seen in Figure 9.

![Figure 9: The transition to state 7 in Hypothermia for bass drum, showing the notation for first striking the drum and then pressing against the drum skin.](image)
When the percussion player is striking the drum, the aforementioned feedback loop is interrupted and replaced by the natural ringing of the drum. This effect is greatly exaggerated by the use of compression in the feedback loop, since the compressor in this case is lowering the amplitude of the signal sent to the loudspeaker, and the listener instead hears more of the acoustic sound of the gran cassa. The ringing of the gran cassa is then picked up by the feedback, effectively extending the instrument’s natural sustain. This is in fact how the piece begins – the percussion player strikes the drum, and the feedback is slowly introduced, which combines into a gesture where the striking of the drum sets the resulting feedback into motion. Denis Smalley defined a gesture as “an energy-motion trajectory which excites the sounding body, creating spectromorphological life” (1997, p. 111, original emphasis), and in that line of thinking the feedback in Hypothermia for bass drum adds to and extends the spectromorphology of the sound of the struck drum. The two causes of the sound – the strike and the feedback – suddenly are combined into one sounding body, aimed to be experienced as the same sound source creating a single musical gesture. However, the sound can then sustain indefinitely, interrupting the spectromorphological expectations.\footnote{Denis Smalley wrote that “the [spectromorphological] archetypes and their variants demonstrate [...] that the note trains us in spectromorphological expectation. [...] We predict or try to predict the expected tendencies of spectral change.” (Smalley 1997, p. 113, original emphasis).}

When the percussion player is pressing on the drum skin with their mallet, the drum skin’s vibration against the mallet creates another audible pitch. It also results in the drum skin being tightened, changing the timbre and pitch of the feedback. The result is the percussion player affecting and interacting with the feedback.

The two players are interacting with the same feedback system: the percussion player by striking and pressing a mallet against the drum skin, and the electronics player by changing the parameters of the feedback. In artist Knut Aufermanns words, the two players are “[learning] how to communicate with [the feedback system]” (Aufermann 2005, p. 493). They are collaborating, interacting with the same sounding body, interrupting the body in question’s “process of self-organization” (ibid., p. 493).

4.1.5 MHS\text{ho}

MHS\text{ho}\footnote{https://github.com/mattiashallsten/mh-sho} is an extension for the SuperCollider programming environment I have written to model the musical structure of traditional shō playing, and is used by the electronics player in Hypothermia for bass drum together with the feedback and low sine waves. Both the aitake and the te-utsuri are implemented in MHS\text{ho}, and the notes of the chords are generated by unfiltered sawtooth waves.
The first time an aitake is heard in *Hypothermia for bass drum* is during the transition to state 5, and the aitake is started together with a loud strike on the drum skin, see Figure 10. This is my interpretation of the serious and sombre qualities I find in gagaku music, echoing the sound of the *da-daiko* drum, used in performances of bugaku\(^\text{14}\) (Nelson 2017b, p. 52), filling the performance space and matching the slow movements of the bugaku dancers. The aitake played is *bi* (美, see Figure 3 on page 4). The loud strike on the gran cassa in combination with the bi aitake is followed by a second strike on the drum, and then a slow trill that increases and decreases in dynamics, ending in the aitake being changed to the aitake *bō* (凢, see Figure 3 on page 4). When the aitake changes, it follows the te-utsuri patterns previously discussed.

![Figure 10: The first aitake in “Hypothermia for bass drum”](image)

The second time an aitake is started without transitioning from a previous aitake is in the transition to state 7, when the first variant of the aitake *jū* (十, see Figure 3 on page 4), is played. There is a second variant of *jū* that adds the note F\(^{\#}\) (ge) below the G\(^{\#}\), and the F\(^{\#}\) is added during the transition to state 8.

As well as relating the form of *Hypothermia for bass drum* to its inspiration – the shō tradition – the sound of MHSho also serves as a way to open up the overall timbre of the piece. Throughout the piece, the spectral content is primarily focused on low-end sounds, and the addition of MHSho on certain parts extends the material both harmonically and timbrally. On top of this, the attack and release portions of the amplitude envelope of the sawtooth waves used in MHSho are quite short in contrast to the slow and evolving changes in timbre created by the feedback and low sine waves.

\(^{14}\)Bugaku is the style of gagaku involving dance (Malm 1959, p. 77).
During the te-utsuri transitions, this adds a layer of subtle rhythmic complexity.

The first and second time an aitake is started without transitioning from another aitake, as outlined above, it is played together with a strike on the drum. The last time an aitake is played, however, it is not played together with a strike on the drum, but rather manually faded in. This is during the transition to state 10. By fading in the sound of MHSho in this way, it is presented together with the other slowly evolving sounds – the feedback and the low sine waves – and not together with the sound of striking the drum. Hypothermia for bass drum then ends by fading out all sounds together.
4.2  **Stycke för cembalo och elektronik**

**Title:**  *Stycke för cembalo och elektronik*

**Duration:**  7'45"

**Instrumentation:**  Harpsichord, Loudspeaker, SuperCollider

**Premiere:**  2021-05-20 by Johann Fritsche and Mattias Hållsten

**Venue for premiere:**  Lilla Salen, KMH

4.2.1  **Instrumentation and staging**

The instrumentation for *Stycke för cembalo och elektronik* consists of an acoustic harpsichord and custom software written in SuperCollider playing back harpsichord samples (called *computer harpsichord* below). The computer harpsichord is played back through a pair of small loudspeakers, placed as closely as possible to the acoustic harpsichord, and the amplitude of the computer harpsichord is matched to that of the acoustic harpsichord. The samples used by the computer harpsichord are recordings of the acoustic harpsichord.

There is also a tape part that plays during the second half of the piece. The tape part is available as a stereo file or as an *Ambisonics* B-format file,\(^\text{15}\) so it can be played back either by a regular PA or a loudspeaker array. When it starts the sound of the two harpsichords gradually gets projected through the PA system in the venue.

The piece is performed by two musicians, one playing the acoustic harpsichord and one playing the computer harpsichord. It is also encouraged that a third person (for example the sound engineer) controls the parameters of the computer harpsichord.

4.2.2  **Cembalo**

The computer harpsichord part is played using the SuperCollider extension *Cembalo*,\(^\text{16}\) which I wrote in the process of composing the piece. *Cembalo* is a sample player that is able to play back not only the sound of the pressing down of a key, but also the sound of the letting go of a key, the latter being one of the particular characteristics of the harpsichord sound. The user can specify a tuning for *Cembalo*, either by (a) selecting between a number of preset temperaments,\(^\text{17}\) (b) providing a

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\(^{15}\)Ambisonics is a format for 3D audio, and the B-format file is an intermediary ambisonics format that can be decoded to practically any loudspeaker configuration (Waves Audio 2017).

\(^{16}\)https://github.com/mattiashallsten/cembalo

\(^{17}\)As of writing this text the available preset temperaments are *twelve-tone equal temperament*, *quarter-comma mean-tone*, *Werckminster III*, *Vallotti* tuning, *pythagorean tuning*, as well as rudimentary 5-limit and 7-limit just intonation scales.
list containing numbers representing a just intonation scale or (c) providing a number representing a fraction of a syntonic comma, used for defining a custom meantone scale (see Figure 11).

```java
// Define a Cembalo object
c = Cembalo.new();

// (a) Set to pythagorean tuning
c.setTuning('pyth');

// (b) Set the tuning to an arbitrary just intonation tuning
1/1,  // C
16/15, // C#
9/8,   // D
7/6,   // Eb
5/4,   // E
4/3,   // F
11/8,  // F#
3/2,   // G
14/9,  // Ab
27/16, // A
7/4,   // Bb
15/8,  // B
]

// (c) Set to two-sevenths comma meantone tuning
c.setTuning(2/7);
```

Figure 11: Setting the tuning of Cembalo.

On top of specifying a tuning, the user can also use the parameters timbre, attack and release to control the timbre of the computer harpsichord. The attack and release parameters introduce a fade in and fade out portion of the volume envelope, respectively, and the timbre parameter controls what samples to use: if the timbre parameter is set to above 0.0, Cembalo chooses a sample with a lower pitch than the user expects and plays it back at a higher rate, resulting in the correct pitch but a thinner sound. If the timbre parameter is set to below 0.0, Cembalo chooses a sample with a higher pitch and plays it back at a lower rate, resulting in a duller sound. See Figure 12 for a spectrogram of the same note played with different settings on the timbre parameter.

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18 The difference between a just major third (5:4) and a pythagorean major third (81:64): 81:80 (Nicholson and Sabat 2018, p. 10).

19 This technique was largely inspired by the song In My Life (1965) by The Beatles, where producer George Martin recorded a piano with the tape at half speed, changing the sound when it was played back at normal speed (Lewisohn and P. McCartney 1988, p. 65).
By using these two properties of the computer harpsichord – tuning and timbre – the computer harpsichord can gradually move from sharing the same sound source as the acoustic harpsichord to diffusing this relationship. At first, the sound of the computer harpsichord is heard as originating from the acoustic harpsichord. As the timbre changes and more complex harmonic content is introduced it becomes apparent that the computer harpsichord is in fact a different sound source than the acoustic harpsichord.

Philosopher Casey O’Callaghan, in proposing his event view on the ontology of sound, defines sound as “the events in which a medium is disturbed or changed or set into motion in a wave-like way by the motions of bodies” (O’Callaghan 2009, p. 36), which in my reading puts great emphasis on a sound’s sound source – the sound exists in how the sound source disturbs its surrounding medium. Furthermore, in the process of transmission the body that is disturbing the medium might be something new – a sound passing through a window or bouncing off of a wall in a reverberant hall, for example. However, we are according to O’Callaghan biased towards experiencing the original sound event as the actual sound event (ibid., p. 40). Even through transmission, we seek to experience the original sound source. Sound amplification as well as reproduction through means of recording is also a form of transmission, and O’Callaghan argues that “sound reproduction technology grounds a form of perceptual access to the sound[, which is] mediated and, therefore, indirect [...] This form of indirectness [...] does not preclude a kind of genuine awareness” (O’Callaghan 2007, p. 144, original emphasis).

Through means of recorded sound comes the “power to create, deform, or reformulate that event”, as described by Rick Altman (1992, p. 25). One might argue that the act of simply recording a sound, without any treatment, reconfigures the sound’s ontology, making it impossible to speak of the sound heard through loudspeakers as the same sound as the original sound event. Composer R. Murray Schafer came up with the term schizophonia to describe this phenomenon, “the cutting
free of sound from its natural origin” (Schafer 1969, p. 46). I choose to not be as dogmatic – I believe that if a recorded sound remains unaffected, it can still be perceived as the same sound source.

Initially, when the sound of the computer harpsichord is not processed, the sound of the computer harpsichord appears as coming from the acoustic harpsichord. By presenting the sounds together, in close spatial and temporal proximity, the two different sounds appear as sharing the same sound source. Even though we hear the sound of the harpsichord being played back by a loudspeaker, we still hear it as the event of the harpsichord plectrums plucking the strings. However, when the sound of the computer harpsichord is altered, this conviction slowly gets questioned until it eventually is clear that they are in fact two different sound sources.

4.2.3 Tuning

The acoustic harpsichord is tuned to Vallotti temperament, which is a commonly used temperament for playing early music (Duffin 2017). *Stycke för cembalo och elektronik* is in the key of F♯ minor, where in Vallotti temperament the fifth (F♯ to C♯: 3:2), major second (F♯ to G♯: 9:8) and fourth (F♯ to B♭: 4:3) are pure. These intervals served as the foundation for composing *Stycke för cembalo och elektronik*, and it was the fact that these intervals are pure in the key of F♯ in Vallotti temperament that made me choose to compose the piece in the key of F♯. Apart from the pure intervals, the acoustic harpsichord also plays the notes A♮, which is just 2 cents sharp of 12TET in Vallotti, and E♮, which is the same as 12TET in Vallotti.

The computer harpsichord enters in bar 9, and apart from the interval 11:10, all of its intervals are tuned to 7-limit just intonation, omitting intervals with the prime factor 5. Consequently, the harmonic space they occupy, apart from 11:10, is three-dimensional, with intervals derived from the prime factors 2, 3 and 7. In bar 25, prepared with a glissando in the end of bar 24, the intervals 6:5, 9:5 and 27:20 are introduced, expanding the harmonic space to also contain the dimension derived from the prime factor 5. These specific intervals give the harmonic material a somewhat melancholic quality, but most importantly they open up and expand upon the harmonic framework of the piece. I see this as an example of the much finer granularity that just intonation provides compared to 12TET when it comes to harmony. See Figure 13 for a three-dimensional graph representing the tuning of the computer harpsichord, omitting the interval 11:10.
4.2.4 Musical form

The piece starts out with the acoustic harpsichord playing by itself, and in bar 9 the computer harpsichord enters (see Figure 14). The tempo is derived from listening for the sustain of the harpsichord sound – when the sound fades out, the musicians should move to the next bar. The reason for this is highlight the spectromorphology of the harpsichord sound, and to allow for the listener to really focus on the timbre of the harpsichord. Also, it creates a situation where the musician playing the acoustic harpsichord has a degree of freedom they would not have if the tempo was set, and creates an opportunity for dialogue between the two musicians. When the computer harpsichord enters, it plays the same melodic figure as the acoustic harpsichord did, but by varying the intonation on the notes it expands upon the harmonic space defined by the acoustic harpsichord playing by itself.

In bar 37 the tempo 46 BPM is introduced, and in bar 43 the tape part starts. At a certain point in the piece, the sound of the two harpsichords is projected through the PA system in the venue. This produces a perceptual shift, from a fragile, soft and localized sound source to a sound without a body but with much more weight. The tape part contains both processed harpsichord recordings, relating it to the sound of the harpsichord, as well as feedback recordings, sounding almost as resonant echoes of the harpsichord. This, combined with how the computer harpsichord sound changes from being perceived as acoustic to being perceived as electronic by using the different sound shaping options available in Cembalo, changes the overall spatial as well as timbral perspective of the piece. The timbral alterations that are performed to the computer harpsichord
sound are (a) to lower the \textit{timbre} parameter, resulting in a duller sound, and (b) increasing the \textit{release} parameter, which in \textit{Cembalo} results in the playback ignoring the sound of the letting go of the key: as previously stated this is one of the most crucial characteristics of the harpsichord sound. This results in a change of the computer harpsichords spectromorphological expectations, altering the acoustic harpsichord and computer harpsichord’s spectromorphological relationship. On top of this, the amplification of the acoustic harpsichord results in its sound being much louder than expected.

The relationship between the acoustic harpsichord and the computer harpsichord is now defined using the tape part, acting as resonances shared between the two, now separate, sound sources. The alterations of the computer harpsichord sound makes it sound almost synthesized, which ties it together with the tape part, and by amplifying the sound of the acoustic harpsichord it is possible to achieve a blend of the sound sources in the PA.

The tape part continues playing until the end of the piece. If timed correctly, both the acoustic
harpsichord part and the computer harpsichord part should finish right before the tape part, so that the tape part continues ringing after the harpsichord sounds have faded. As mentioned earlier, the tape part works as a resonance or echo of the harpsichord sound, which is made clearer by letting it ring out after all other sounds have faded.
4.3 Breathing, bowing

Title: Breathing, bowing
Duration: Approx. 19’00”
Instrumentation: Bass viol, Steel plate, SuperCollider
Premiere: 2022-05-16 by Louise Agnani and Mattias Hållsten
Venue of premiere: Nathan Milstein-salen, KMH

4.3.1 Instrumentation and musical form

The instrumentation for Breathing, bowing consists of a bass viol and a transducer attached to a sheet of suspended stainless steel, referred to as the plate below. The plate is used for playing back synthesized sound, as well as amplifying the viol at certain parts of the piece. The staging has the viol player on stage left and the plate on stage right, as well as one person playing the electronics offstage but with a clear line of sight to the viol player. The sound of the viol is also picked up by a microphone, and the signal is routed through a mixer, allowing the sound of the viol to be played back through the plate.

Breathing, bowing consists of three distinct parts: the first part opens with the viol playing by itself, and the synthesis is later added. The second part is purely electronic and will be henceforth referred to as the tape part, and the third part contains both viol and electronics.

4.3.2 Tuning of the viol

A six-stringed bass viol is usually tuned in fourths, with a major third in the middle: (from the lowest string) D, G, C, E, A, D. Sometimes the temperament is adjusted by both adjusting the tuning of the strings and changing the position of the movable frets (Dolata 2016, p. 206). In Breathing, bowing, the viol is tuned in only pure fourths (C#, F#, B, E, A, D) and the frets are adjusted to be able to play intervals in seven-limit just intonation (see the resulting frequency ratios in Figure 15). The written score contains instructions on how to tune the viol and place the frets, much like tuning instructions for historical temperaments in the context of tuning organs or other keyboard instruments, with the intention of it being possible to find the correct fret placements by ear. The only intervals that the viol player has to be able to tune by ear when finding the correct fret positions are a pure fourth (4:3), pure fifth (3:2), unison (1:1) and harmonic seventh (7:4). I have found all these intervals to be rather easy to teach musicians, especially if the musicians are specialized in early music, as many viol players are.
The resulting pitches can be expressed as a chromatic scale, but all the semitones are seven-limit semitones (28:27) and all the whole tones are pythagorean whole-tones (9:8), with the exception of the fifth fret which is split between 21:16 and 4:3. This allows for a three-dimensional harmonic space: see Figure 16 for a graph representing the intervals used in the context of *Breathing, bowing*, where the x-axis represents a 3:2 interval and the y-axis a 7:4 interval. The way that the electronics and the viol interact in *Breathing, bowing* depends most of all on their pitches, and gaining precise control of the pitches of the viol is necessary for the desired effects to arise.

![Figure 16: A graph representing the intervals used in *Breathing, bowing*. The note names correspond to how they are notated in HEJI notation.](image)

### 4.3.3 The plate

By using the plate, the electronic sound is given a body. First of all, positioning the plate on stage has the intention of the listener attaching the sound of the plate to the actual plate. Second, when playing back sound through the plate, the intent is that the sound should be spectrally altered, in
contrast to a full-range loudspeaker that attempts to give a transparent representation of the sound. The plate transforms the sounds that are played back through it, creating something new. The plate has very clear resonances, and in the process of composition I have both worked with and against these specificities of the plate.

In the parts of Breathing, bowing where the plate and the viol play together, the sounds that are played back through the plate have one of two musical functions: they either server to articulate the harmonics of the bass viol, expanding its timbre, or they are used to create chords with the bass viol, expanding its harmonic space. Since their pitches are tuned in just intonation, the difference between these two functions can be blurry – as Robert Hasegawa describes it in his analysis of Michael Harrison’s piece Revelation (2007) for justly tuned piano, musical notes tuned in just intonation “make chimeric perceptions particularly likely, since overtones of the sounding pitches can easily merge into chimeric harmonic spectra” (Hasegawa 2021, p. 535).

In bar 18 of Breathing, bowing (see Figure 17), the chord \([D^\# - E_\#] - B^\# - A^\#\) is played. The note \(A^\#\) is used to articulate the third overtone of the note \(D^\#\), since the third overtone is prevalent in the timbre of the viol – if this was not the case, it would form a dissonance with the note \(E_\#\), forming the interval 21:16. Since its function is to articulate a harmonic, this dissonance is masked.

\[\text{Figure 17: Bars 16-18 of Breathing, bowing.}\]

In bar 32, the chord \([C^\# - E_\#] - A^\# - B^\#\) is played, where the \(A^\#\) is one fourth + one octave above the \(E_\#\). This creates a first inversion A major chord, with an added ninth, and the relationship between the third \((C^\#)\) and the ninth \((B^\#)\) is a 7:2 – this is the reason for the ninth being lowered. However, this causes dissonance with the \(E_\#\) of the viol, creating the interval 21:8. In the following bar, however, the chord \([C^\# - E_\# - A^\#] - B^\#\) is played, raising both the third \((C^\#)\) and the ninth \((B^\#)\) by a septimal comma. This creates a chord where the relationship between the third and the ninth remains (7:2), but the ninth is pure in relation to the fifth \((E_\#)\), again articulating the third overtone.

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20 The box surrounding some notes indicate what notes are played by the viol.
of the note E₃ played by the viol. For visual aid in understanding how these notes relate to one another, see Figure 16 on page 29.

It is primarily sine waves that are played back through the plate. In parts of the piece, however, the sine waves transform into more complex sounds by the means of phase modulation. When this happens, the notes tend to not work as well in articulating harmonics of the viol, and they serve a much more obvious harmonic rather than timbral function. This is due to that they now contain much richer spectral content, in contrast to pure sine waves that, at least in theory, have none.

In the tape part I have taken a different approach. In composing the tape part I have, rather than following a strict just intonation framework as with the other two parts, purely listened to the resonances of the plate. I tried utilizing different methods when doing so, for example by analysing the emerging intervals between the resonances and using them as constructors for a musical scale. However, I found that the most fruitful way of choosing pitches was simply listening for the resonances that appeared and intuitively writing chords and melodies based on those resonances, rather than constructing a strict system.

Rather than using a harmonic overtone series, I used the inharmonic resonances of the plate as the source of intervals. When playing the resonant pitches through the plate, the plate often responded by producing additional tones – sometimes these tones were very close to the incoming sound’s frequency, resulting in a simple sine wave producing intense beatings when played back through the plate, and sometimes they were octaves, fifths of fourths below the frequency of the incoming signal (see Figure 18 for a spectrogram of one part of the piece where this occurs). On top of this, the plate’s response changes when playing back multiple resonant frequencies through it. For example, a very clear response an octave below the frequency of one incoming sound could be drastically obstructed by adding an additional incoming sound. This makes way for composing musical gestures not only in the incoming sounds, but also in the way the plate responds to the incoming sounds. By doing so, the spectromorphological tendencies of the plate are revealed and exploited, which I have found to be one way of achieving the goal of giving the sound a body.

4.3.4 Tempo and the final part

The first part has no set tempo. During the first three bars the tempo guided by cues given by the electronics player, letting each bar last around 30-40 seconds. In bar 4, however, the tempo is instead derived from the bowing of the viol player: for each bar there is an indication on how many bows that bar should contain. This process repeats two times, alternating between the electronics
player and the viol player deciding the tempo. This allows for more freedom for the viol player, and creates the opportunity for them to engage with the sounding material to a greater extent.

In the third part, a tempo of 144 BPM is introduced, and the material is more like a harmonic progression than in the first part. The harmonic progression is repeated four times in total. The first two times the progression is played, the viol player plays one bow per bar, which constrains the viol player both in dynamics and expression due to the slow tempo. However, the final two times the progression is played, the viol player plays two bows per bar. This releases the constrains, and lets the musician be much more expressive and gives the progression more energy and interaction between the viol player and the electronics player. The piece ends simply by fading out the final chord.
4.4 Solo #1

Title: Solo #1
Duration: 14’30”
Instrumentation: Shō, Electronics
Premiere: 2022-04-07 by Mattias Hållsten
Venue of premiere: Benhuset, Katarina Kyrka

In 2022 I started taking lessons in the shō by my teacher Ishikawa Ko. At the time of writing, I am currently practising the different aitake, a few te-utsuri, the *shōga*\(^{21}\) for the gagaku piece *Etenraku* as well as the netori and *choshi*\(^{22}\) for the hyojo mode. On top of learning the tradition, I have also started exploring the instrument in relation to my current artistic practice, and on 7/4 – 2022 I performed a newly written piece entitled *Solo #1* for shō and justly tuned unfiltered sawtooth waves at the concert series Skaiv\(^{23}\) at the venue Benhuset.\(^{24}\)

4.4.1 Instrumentation and staging

The venue Benhuset is located at the cemetery of Katarina Kyrka, and is a quite small venue with about 50 seated audience members. I wanted to play the shō without any amplification, and I was pleasantly surprised that the venue had quite prevalent acoustics, allowing me to do so. This also led me to reflect upon the fact that I had never properly heard anyone else play the shō – I had only heard either myself play it, from the perspective of a musician, or heard a recording of it, either on a studio recording or through Zoom lessons with my teacher. I was unsure how loud the instrument was, but I trusted the sound technician when he said that the shō was loud enough. My original intention was to play back the sawtooth wave through a loudspeaker placed next to me, in order to localize the electronics close to the shō. This was unfortunately not possible, and the sawtooth waves was instead played back through the house PA. I was expecting the sawtooth waves to sound localized to the speakers, but instead both them and the sound of the shō was diffused in the room, probably due to their timbre as well as the room acoustics.

The electronics used in *Solo #1* are generated by a SuperCollider patch that allows me to define a series of chords and step through them using a foot pedal, playing back the chords using unfiltered sawtooth waves with a relatively slow amplitude envelope. Some of the chordal changes are done by simply changing the notes, and some by playing glissandi from one note to the next. This gives

\(^{21}\)Shōga is the method of transmission for gagaku pieces; see Tokita and Hughes 2017, p. 17.

\(^{22}\)Choshi serves the same function as the netori but is longer (Togi et al. 1971, p. 72).

\(^{23}\)https://skaiv.se/

\(^{24}\)https://www.svenskakyrkan.se/katarina-/benhuset
rise to interesting interactions between the sound of the shō and the sound of the sawtooth waves, for example when a very strong dissonance such as a semitone is resolved to a unison.

4.4.2 Tuning

Since the shō is tuned in pythagorean tuning, as previously mentioned it generates a two-dimensional harmonic space. The pitches of the instruments are fixed to that harmonic space, apart from the possibility of slightly bending the notes upward with range of about a whole tone by means of covering only parts of the holes of the pipes. This technique is however not stable enough for a novice shō player like myself to employ it consistently. By producing septimal intervals with the sawtooth waves, the harmonic space of the shō can be expanded. See Figure 19 for a graph representing the intervals used in Solo #1.

\[
\begin{array}{cccccccc}
7/6 & & 7/4 & & \\
C^\flat & & G^\flat & & \\
4/3 & & 1/1 & & 3/2 & & 9/8 & & 27/16 \\
D^\flat & & A^\flat & & E^\flat & & B^\flat & & F^\# \\
23/21 & & 8/7 & & 12/7 & & 9/7 & & \\
E_r & & B_r & & F^\# & & C^\# & & \\
\end{array}
\]

Figure 19: A graph representing the intervals used in Live at Benhuset. The x-axis represents a 3:2 interval and the y-axis represents a 7:4 interval. The note names correspond to how they are named in HEJI notation.

I have used two different approaches to choosing the pitches to be played by both the shō and the sawtooth waves:

1. Presenting the pitches of the shō as the reference pitch, for example by playing the pure fifth A - E on the shō and complementing it by playing 7:4 from A (G\flat above A) using the sawtooth waves, generating the chord \[
\begin{bmatrix}4:6:7\end{bmatrix}.
\]

   Here the sawtooth waves are expanding the harmonic space of the shō.

\textsuperscript{25}The box surrounding some notes indicate what notes are played by the shō.
2. Presenting the pitches of the sawtooth waves as the reference pitch, for example by playing the note E on the shō and playing a 7:4 below the E (F#. below E) with the sawtooth waves, producing a chord where the pitch of the sawtooth waves is perceived as the fundamental and the E of the shō is perceived as the 7:4 above that note, i.e. \( 4:7 \). Here the shō is expanding the harmonic space of the sawtooth waves.

In some sections of the music, the harmonic framework is shifted from the first variant to the second. For example, the chord \( A\# - C\# - [D\# - E\#] (6:7:8:9) \) chord 6 in Figure 20) is a clear example of the first variant – the \( D\# \) and \( E\# \) notes are played by the shō, and the \( A\# \) and \( C\# \) notes are played by the sawtooth waves, expanding the harmonic space of the shō with the seven-limit interval 7:8 in relation to the note \( D\# \). In the following chord, the \( D\# \) of the shō is held while the \( C\# \) of the sawtooth waves glides to a \( B\# \), a 7:6 under the \( D\# \), producing the chord \( 6:7 \). In the following chord, a \( E\# \) is added, a 3:2 under the \( B\# \) and a 7:4 under the \( D\# \), producing the chord \( 4:6:7 \). Now, the shō is playing the 7:4.

A similar technique of shifting the root note of the chord by means of altering the intonation of certain notes can be found in other just intonation works, for example in KOAN for String Quartet (1984) by James Tenney. In KOAN, the interval played starts out being a pure fifth G - D. As the piece progresses, the pitch of the upper note stays consistent while the lower note slowly rises, resting at just intervals. The piece starts out with the D resting at the third partial of the periodicity pitch, but as the lower note shifts in the second bar it creates the harmonic relationship 27:40, where suddenly the D is the 40th partial of the periodicity pitch. In the B section of the piece, the dyads are instead changed to triads, further increasing the experience of a periodicity pitch on certain chords.

Another piece that utilizes a similar technique is HARMONIUM (GLISTENING) (2021a) by Thomas Nicholson. The piece starts out with a low C\#, by itself sounding as a root note. The second note that enters is a D\#, sounding as a 8:7 above the C\#. The third note, however, is a A\#, the
as a 3:2 above the D. This presents an ambiguity – the first note C# could both be interpreted as still being the root note, but it could also be interpreted as the harmonic seventh, played one octave lower than the root note D. The fourth note, E#, furthers this ambiguity – should it be interpreted as the minor ninth to the root note D, or the major tenth of the root note C? This sort of harmonic ambiguity is characteristic of a lot of modern works in just intonation, and is something I aim to explore further.

4.4.3 Musical form and gestures

Along with the specific tuning of the shō and the sawtooth waves, Solo #1 is very simple in its musical form. A total of 20 chords are played in sequence, grouped in three longer phrases. The first phrase starts with a rather simple seven-limit just intonation chord, A# - G# - A# - B# - E (4:7:9:12), in a A# tonality. It ends with a modulation from the note A# as the key center to the note E as the key center, through means of the glissando from C# to B#, as explained earlier (moving from chord 6 to chord 7), and ends on a 4:6:7 consonance (E# : B# : D#) and then fades out.

The next phrase starts with another seven-limit consonance, this time playing the notes F# : E, slowly introducing the note C#, and adding the notes B# and D# on the shō to add dissonance. During this phrase, a dissonant interaction between the shō and the sawtooth waves is heard, that resolves to the same seven-limit consonance it started on. The final phrase is just a repetition of the second phrase, but with an alteration in how it starts in order to transition between the F# tonality of the second phrase to the A# tonality of the first phrase.

The te-utsuri used in traditional shō playing for moving from one aitake to the next are often constructed so that the notes change right before or right after the musician changes their breathing direction. The te-utsuri are usually grouped in beats of four, and the change often happens sometime around the fourth beat. In Figure 21 I have notated the te-utsuri used for changing between the aitake ku (工) to the aitake bo (凢) as I have been instructed by my teacher.

When changing chords in Solo #1, I have tried to somewhat emulate this general gesture. When changing from the second to the third chord (see Figure 20), for example, I add the note A# right before I change my breathing direction, and change the chord of the sawtooth waves together with my breath change. While playing a music that is not traditional, by doing so I still relate the material to the tradition of aitake and te-utsuri, organizing the chords as states and transitions similarly to how the musical form of Hypothermia for bass drum is constructed.

On a personal note, I remember in 2021 how I, in anticipation of learning to play the shō,
expressed to a dear friend how “I was just looking forward to have the instrument in my hand, sit down and breathe, and let that be my musical practice.” In a sense, this is what I have done when composing Solo #1. This thought about breathing will be further elaborated in Section 5.4.
5 Formulating a practice

One of the major turning points for my artistic practice this year has been to start learning the shō. To me this shift signifies not only an extended palette of sounds possible but also a change in my relationship to the sounding material. In the pieces Hypothermia for bass drum, Stycke för cembalo och elektronik and Breathing, bowing, I wanted to explore other forms of musical expression than the fixed media format. I did this by writing pieces for acoustic instruments and electronics. However, I wanted to let the electronics also be live, and because I was not comfortable in letting anyone other than me play the live electronics they have thus far been performed by me.

But in spite sharing the role of performer between a musician and myself, I was still present in the role of composer. There was still a clear hierarchy, where the musician simply followed my instructions. In this section I will discuss how the topics discussed in this text, on top of being tools for aesthetics, has influenced how I imagine my artistic practice going forward, where I as a composer have a similar relationship to the material as the musicians performing it and the hierarchy is not as clear. These ideas and ideals for musical performance are also greatly influenced by how I have started learning and performing music with the shō – I will in this section describe my experience performing Solo #1, and how that was an experience of engaging with the material by simply breathing, continuously listening to the sounding result. I will also discuss how I have found tendencies of this sort of musical practice already present in the pieces.

5.1 Tempo

One of the things that can shape the hierarchy that I am discussing is the tempo of the music. In many parts of Hypothermia for bass drum, Stycke för cembalo och elektronik and Breathing, bowing, a clear tempo does not exist, at least not in the typical sense.

In Hypothermia for bass drum, the changes that occur in harmony and timbre are strictly dependent on my intuition at the moment of the performance. Although I have an idea of how long each part should take and follow that using a stop watch, there is still a degree of improvisation given to me in terms of the temporal developments. The musician, however, have no say in this. They just follow my lead.

In Stycke för cembalo och elektronik, the tempo up until bar 37 is derived from the sustain of the harpsichord. When both musicians hear that the harpsichord sound has faded out, they simultaneously move to the next bar. Also, the first eight bars of the piece are played by the acoustic harpsichord player alone, allowing them to, in their own pace, create a relationship with
the harpsichord timbre. When the computer harpsichord enters, the tempo, determined by at what threshold the acoustic harpsichord player thinks that the harpsichord sound has properly faded out, is already set by the acoustic harpsichord player.

_Breathing, bowing_ is written in a way that lets the control of the tempo oscillate between the electronics player (in the opening bars, for example) and the viol player (in bars 4-6). This allows for there to exist a clearer interplay between me and the musician, that is not just dependent on me nodding to the musician when to change chords. When the viol returns after the tape part, the tempo is set to 50 BPM. However, when I have participated in performing the piece it has been the viol player who has been in charge of the tempo: during the first two repetitions of the final harmonic progression, the viol player bows one time per bar, and in the final two repetitions of the harmonic progression the viol player bows two times per bar. As the electronics player, I have simply listened for the viol players bowing, rather than tried to count beats in the specified tempo.

5.2 The use of feedback in _Hypothermia for bass drum_

The feedback in _Hypothermia for bass drum_, on top of giving the electronic sound a body, creates a structure where both me and the musician interacts with the same process. Although I have a greater deal of control – I am at liberty to switch off the feedback at any moment – it is still a collaborative exploration of a single phenomena. The feedback, even though it was I who designed its system, is something initially alien to both of us.

The parts that the percussion player performs is thus a way for them to also explore the behaviour of the feedback. In particular when they press the mallet at the drum skin, they listen for the resulting timbral shift, interacting with the feedback.

5.3 Tuning

One of the more curious aspects of just intonation, as I have outlined in Section 3.4, is that the desired pitch heights can be found within the sound. Although the harmonic space of a given piece is decided by the pitches that the composer writes in the score, when actually finding these pitches the musicians explore the sounding phenomena rather than a preconceived notion of pitch height.

What the musicians then do, especially if it is an ensemble piece, is learning about what pitches to play _from the pitches that they are playing_. I think this is crucial. The correct pitch-heights are found in the sound itself, _not_ from the composer’s vision.

During the premiere of _Hypothermia for bass drum_, I was allowed a great deal of freedom in tuning the low sine waves, discussed in Section 4.1.1. The pitch of the feedback depends not only
on the position of the speaker and microphones and the tuning of the bass drum, but also on the people in the room. I noticed that the feedback sounded completely different during rehearsals than during the concert, causing me to allow for re-tuning the low sine waves during the performance.

In that situation, I was searching for the correct pitch height within the sound of the feedback. The correct pitch height only existed within the context of that specific performance – when performing the piece at a later point, these pitches would be different. When the pitches aligned, the timbre either intensified or came to a rest. And as I have explained in Section 4.1.2, this was done in a rather intuitive, not necessarily in accordance to a rigid just intonation system. However, it was only I who could change these pitches. The percussion player had no say in this.

In *Breathing, bowing*, as discussed in Section 4.3.2, the tuning is very particular. However, I wanted to make sure that the viol player would be able to tune their instrument by ear. In the written score I have included instructions on how to tune the instrument. Although the pitches are fixed during the performance, having the musician tune their instrument by ear leads to them hopefully creating an embodied relationship with the intervals, rather than adjusting the pitch while looking at a tuning machine. Additionally, when composing the tape part of the piece, featuring only the plate, I discovered the pitches by exploring how the plate responded to different pitches. Similarly to *Hypothermia for bass drum*, where the correct pitch heights were found within the sound of the feedback, in *Breathing, bowing* the correct pitch heights were found within the frequency response of the plate. Just as with just intonation, finding the correct pitch heights was an act of exploring the sounding phenomenon.

When tuning to just intonation, musicians discover how their pitches are positioned in the harmonic space, and how this ultimately relates to how our auditory system perceives pitch. In Thomas Nicholson’s master thesis, he writes that when using intervals with a high prime-limit “[r]ather than merely extending the music’s conceptual prime-limit, a listener’s focus might be extended, quite experimentally, upward in the series, compelled to confront a sound’s richness of timbral interaction” (Nicholson 2021b, p. 55). This proposes that just intonation reveals something about the sound to the listener. Nicholson then quotes Kyle Gann’s analysis of La Monte Young’s *The Well-Tuned Piano* (1987), where Gann writes of the “impressive aural illusions” that makes the piano sound like “foghorns, voices, bells, even machinery, and the ‘missing fundamental’ resulting from the complexes of rationally tuned periodicities” (Gann 1993, p. 149). But, if just intonation reveals something of sound to the listener, it should reveal just as much to the musician. By tuning to just intonation, the musician gains a new understanding of their instrument, their hearing in relation to their instrument, and musical sound overall. And if another musician is added, they
start learning from each other. In terms of my personal relationship to the sounding material, by participating in the performance of a given piece I also participate in this process of discovery.

And similarly to tuning to just intonation, in both Hypothermia for bass drum and Breathing, bowing the tuning was derived from the sounding phenomenon. What ties the practices together is that they are examples of intonation practice that is context-specific, with a focus on listening. Engaging other musicians in this context-specific intonation, that is not necessarily just intonation, is something that I want to address in the future.

5.4 Learning the shō: learning to breathe

The shō is an instrument that is excited by the musicians breath. Obviously, this is not something that sets the shō apart from other instruments – there are plenty of wind instruments around. However, what does set it and other similar free-reed mouth organs apart from other wind instruments is the fact that the musician both inhales and exhales.

When playing other wind instruments, musicians only exhale. As with speech, they exhale when you want to make sound, and inhale when they want to refill their lungs with oxygen to be able to exhale once more. When learning the shō, I have found myself forgetting that the shō is different. When I have exhaled for a period of time, I want to inhale to refill my lungs with oxygen, and I forget that the act of inhaling will also make sound. This disrupts the dynamics of the traditional playing style (a slow crescendo throughout one breath, ending on playing loudly shortly before switching breathing direction and starting soft again), and breaks the focus of the resulting sound. Because of this, my experience learning to play the shō is just as much about learning the instrument as it is about learning to breath. When performing Solo #1, my experience is mostly that of just sitting there, breathing, exciting and simultaneously exploring the sound.

In the article The Accordion (& The Outsider), American composer Pauline Oliveros reflected upon her practice of playing the accordion in relation to breathing:

The ancestor of the accordion, the 4,000-year-old Chinese sheng (mouth organ), is breath-driven with a mouthpiece attached to a gourd resonator with free metal reeds vibrating inside of vertical bamboo pipes fixed into the gourd. There are finger holes in the gourd for changing pitches. The fingers pick up vibration from the gourd. The sheng is a beautifully integrated instrument for breath and touch.

The accordion (invented in 1840 in Vienna) with its keyboard/buttons and bellows remove the reeds from direct human breath, but it’s still a wind instrument with air-driven free reeds. The keys, when pressed, open valves that let the bellows blow air through the reeds to cause them to vibrate. I synchronize my breath with the air in the bellows as the reeds come to life and sound.

Playing the accordion has influenced my interest in breath-oriented music - that is pieces that are shaped
by breath-like rhythms that flow organically as illustrated by *Horse Sings From Cloud*. (Oliveros 2004/2010, p. 155–156, original emphasis)

After first listening to recordings of East Asian mouth organs, and later learning to play the shō, the relationship between Oliveros’ accordion playing in *Horse Sings From Cloud* (1979) and the shō is clear. The harmonic structure used in the 1982 recording of the piece sounds similar to the structure of the aitake used in traditional shō playing, and the focus on breathing makes the overall dynamic and gestural tendencies of the piece like that of traditional shō playing.

These dynamic and gestural tendencies is in my mind one of the more significant aspects of playing an instrument like the shō, where the musician both breaths in and out of the instrument. After having performed *Solo #1* (discussed in Section 4.4), it has become extremely apparent in relation to the static sawtooth waves. Throughout the duration of a breath, the slight changes in pitch made it sound almost as if the sawtooth waves were also moving, and on every change of breath the static nature of the sawtooth waves became apparent, making it clear for a moment in time that one of the sound sources was excited by breath and one of them was excited by electricity. I am certain that this phenomenon occurs when playing other instruments together with static synthesized sound, but it became an extremely profound experience for me. As previously stated, it felt as though all I was doing was breathing, and exploring the sounding result, rather than actually performing a piece of music.

The static sawtooth waves worked as a way to remind me of my breathing, since small changes in my breathing pattern became even more timbrally and harmonically apparent in relation to a static pitch. Similar to how late composer Alvin Lucier’s pieces for acoustic instruments and tone generators reveal something about the sound of the acoustic instrument by relating it to something more controlled (for example the piece *Charles Curtis* (2002) for cello och sine waves), the static sawtooth waves revealed something about the sounds I was making. In contrast to my previous fixed media pieces, that in hindsight all dealt with different sounding phenomena, when playing the shō I get a much more tactile relationship with the sounding result, which results in a kind of embodiment of the knowledge of sound. What I am trying to address is that the process of learning the shō has been many times more profound than I ever expected it to be, while still fulfilling my dream of just sitting there, breathing. I am looking ahead with extreme joy at how my practice as a shō musician will develop moving forward.
6 Conclusion

In this text I have addressed four musical works that have all been in the same series of solo pieces for acoustic instruments and electronics: Hypothermia for bass drum (2020), Stycke för cembalo och elektronik (2021), Breathing, bowing (2022a) and Solo #1 (2022b). I have explained how these pieces relate to my intonation practice, that albeit primarily concerns just intonation, is a practice that is context-specific. I have outlined one of the primary characteristics of just intonation being that of finding pitch-heights within the sound itself, and when discussing the pieces Hypothermia for bass drum and Breathing, bowing I have explained how this characteristic can translate to something that is not easily confined in a rigid just intonation system.

Additionally, I have discussed how my practice as a musician, through learning the shō, is an example of a practice-based research where I through practice can explore and investigate new areas of aesthetics and performance practice.

Finally, in the pieces discussed I have found tendencies, certainly influenced by the process of learning the shō, of considering the relationship between composer and musician, particularly in regards to the degree in which the musician is allowed to them self explore the sounding phenomenon. These tendencies has been related to both tuning (as in Breathing, bowing), tempo (as in Stycke för cembalo och elektronik and Breathing bowing) and the interaction with the same sounding body (as in Hypothermia for bass drum).

I look forward to venture deeper into these territories, and hopefully to one day become a decent shō player.
7 Appendix

Written scores

<table>
<thead>
<tr>
<th>Hypothermia for bass drum</th>
<th>hypothermia-score.pdf</th>
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<tbody>
<tr>
<td>Stycke för cembalo och elektronik</td>
<td>cembalo-score.pdf</td>
</tr>
<tr>
<td>Breathing, bowing</td>
<td>breathing-bowling-score.pdf</td>
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Recordings

<table>
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<tr>
<th>Hypothermia for bass drum</th>
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<td>Breathing, bowing</td>
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</tr>
<tr>
<td>Solo #1</td>
<td>solo-1.wav</td>
</tr>
</tbody>
</table>

*Live at UNM 2021*

*Live at Elektroakustiskt i maj*

*Live at ljudOljud 2022*

*Live at Skaiiv*

Links to referenced recordings and videos

**Music**

- Thomas Nicholson - *HARMONIUM (GLISTENING)*
  - https://youtu.be/Cg8bKSujmKA
- James Tenney - *KOAN for string quartet*
  - https://youtu.be/raNKAtgGRj4
- Tokyo Gakuso - *Hyojo no Netori*
  - https://youtu.be/8HdVuyRXeEk
- Alvin Lucier - *Charles Curtis*
  - https://youtu.be/v-JMQ59pCk
- Pauline Oliveros - *Horse Sings from Cloud*
  - https://youtu.be/5j-IsIPInQY
- La Monte Young - *The Well-Tuned Piano*
  - https://youtu.be/VXxZCSAWUP8
- The Beatles - *In My Life* (piano solo)
  - https://youtu.be/YBcSt0dLQAT?t=87

**Videos**

- Naomi Sato demonstrates the sho
  - https://youtu.be/yUp1F1dZt0
- Instrument: Sheng (Wu Wei)
  - https://youtu.be/qkkA5yWrvww
- Ko Ishikawa live at Multiple Tap 2014
  - https://youtu.be/k9Yl00y84Eg
References

Written references


Aufermann, K (2005). “Feedback and music: you provide the noise, the order comes by itself”. In: *Kybernetes* 34.3/4, pp. 490–496. DOI: https://doi.org/10.1108/03684920510581675.


Ishikawa, Ko (n.d.). *Contemporary music and Sho*.


Musical references


Nicholson, Thomas (2021a). HARMONIUM (GLISTENING). “For ensemble, or soloist with or without electronic support, or fixed media ...”


Online references


