Using Ethnographic Data and Psychoacoustics to Analyse a Tuning System for *Surdulina* Bagpipes

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Abstract

This article offers an insight into the tuning system and tuning method that Santo Trunzo, a bagpiper from Nocera Terinese, uses for his *surdulina* and *conflentana* bagpipes. This tuning system is also used by other bagpipers from the same and different areas of the region. The tuning system is studied in relation to the physical properties of the instrument, the bagpiper's tuning method, the emic perspective on tuning, and the cultural context that produces such a system. The analyses rely on mixed methods that draw on strong ethnographic data, psychoacoustics, and aural and pitch analysis. In describing these, this article proposes a methodological approach to the study of bagpipe tuning that focuses on the perceptive effects produced by harmonic intervals and accounts for both the physical and the cultural components of tuning.

Dati etnografici e teorie psicoacustiche nell'analisi di un sistema di intonazione della surdulina. *Questo articolo offre un'analisi del sistema e del metodo di accordatura che Santo Trunzo, zampognaro di Nocera Terinese, usa per le sue zampogne surduline e conflentane. Questo sistema d'intonazione è anche utilizzato anche da altri zampognari, sia della stessa area che di aree diverse. Il sistema d'intonazione è studiato in relazione alle caratteristiche fisiche dello strumento, al metodo adottato dallo zampognaro, al punto di vista emico sull'intonazione e al contesto culturale cui appartiene. Le analisi utilizzano metodi misti e si fondano su dati etnografici, psicoacustici, sull'analisi uditiva e computerizzata. Il saggio propone un approccio metodologico allo studio dell'intonazione delle zampogne incentrato sugli effetti percettivi prodotti dagli intervalli armonici e tiene in considerazione sia aspetti fisici che culturali dell'intonazione.*

Introduction

This article studies a tuning system used for the *surdulina* bagpipe in Calabria. The analyses presented here rely on mixed methods that draw on strong ethnographic data, psycho-acoustics and pitch analysis. The aim is to offer a methodological approach to the study of bagpipe tuning that takes into account the bagpiper's view of tuning, the process used for tuning the instrument, and the technical and acoustical properties of the bagpipes.

In the landscape of Italian bagpipes, Calabria stands out for its variety and diversity: despite being affected by social changes as much as other Italian regions, Calabrian bagpipes still hold their prestige in the region. The imposition of new social and economic models, which occurred with the economic boom in the 1960s, caused the traditional agro-pastoral society – the elective space of bagpipes – to shrink and become marginalised, and wiped out many types of Italian bagpipes. However, despite the profound transformations that occurred in the region and competition from the modern diatonic accordion, Calabria has kept most of its indigenous instruments in use. Considering the variety of types found and their distribution throughout the region, and thanks to a recent revival movement that has brought renewed interest in the instrument, bagpipes are among the most important instruments in Calabria. There are four main families of bagpipes in Calabria (Scaldaferri 1994) distributed in different geographic areas: *a chiave*, *surdulina*, *a paro* and *a moderna*. All of them belong to the larger family of Central and Southern Italian bagpipes, in which all the sounding pipes are attached to a carved piece of wood called the "stock" (Guizzi, Leydi 1985; Leydi 1979; Guizzi 2002). Each of the Calabrian bagpipe families is then differentiated according to organological features such as the instrument's shape, the pipes' inner bore, acoustic properties, and differences in the sound activation systems or in the fingering. The *zampogna a chiave* is present in two versions: *zampogna a chiave del Pollino,* shared with the region Basilicata is found in the northern part of Calabria (Scaldaferri 2015); *zampogna a chiave delle Serre,* found in the central area of the region, is a Calabrian adaptation of the *zampogna* a chiave which features an extra drone. Both instruments are characterised by two chanters of different length and a key in the left chanter which is activated by the fifth finger. The *surdulina,* found in Basilicata and in the central to northern part of Calabria, features chanters of the same length and the occlusion of the right chanter. It is divided in four types: *surdulina del I tipo* in the north-eastern part of surduline area; *surdulina del II tipo* found in the nort-western part; *stifetta* found in the eastern part; and *conflentana* found in central Tyrrhenian Calabria (La Vena 2002; 2003; 2005). The *zampogna a paro calabrese,* with chanters of the same length and conical bores, is found in the central and southern part of the region in different types that feature singe, double or mixed reeds (Cravero 2006). The *zampoga a moderna,* found in the southern part of Calabria, has two chanters of different lenght and reproduces, without the key, the tuning system of the *zampogna a chiave delle Serre* (La Vena 1994). The variety of models is equalled by the instrument's vast repertoire, which embraces almost every musical scope in the region.

Although there is a vast literature on Calabrian bagpipes, which comprehensively addresses their morphology, repertoire and symbolic functions, few attempts have been made to understand the tuning of these instruments.[1] The available recordings present the listener with a wide variety of tunings that make it difficult, if not impossible, to identify a single reference system even for a sub-type or a sub-area, let alone a single tuning system common to an entire family of bagpipes. Confronted with such a variety of tunings, researchers tend to comment only that some bagpipe pitches diverge somewhat from the corresponding tempered ones. One commonly adopted method uses arrows, pointing up or down, to indicate the deviation of specific pitches – most commonly the fourth and seventh grades of the scale – without, however, providing a quantisation of such a deviation (examples of this method can be found, among others, in Ricci, Tucci 2004; Scaldaferri 2015). By not providing a quantisation of these deviations, such studies suggest how difficult it is to identify a single tuning system that works with all the bagpipes in a family or sub-family. Consequently, researchers rightly identify a general tendency of some pitches to be tuned slightly higher or lower. Furthermore, by referring to the tempered scale this method facilitates the communication of pitch deviation to a western-trained audience. However, taking the tempered scale as a reference fails to convey the bagpiper's perspective on tuning. Bagpipe sound systems, technology and aesthetic models retain features very different from those of the tempered modern instruments. It is, therefore, more than plausible that the tempered scale is an extraneous reference for bagpipers when tuning their instruments.

Drawing on studies in psychoacoustics, Canadian composer and intonation theorist Marc Sabat demonstrates that only a limited number of intervals are tuneable by ear. These intervals, which he calls "consonances", have simple harmonic ratios and their periodicities produce particular perceptive responses. In other words, consonances have special qualities that are defined by the perceived periodicity of their intervals. Sabat points out that non-consonant intervals can be tuned by ear only by approximating a deviation from a consonance. Drawing on Marc Sabat's studies, I will provide a method for analysing bagpipe tuning that takes into account the way bagpipers perceive the intervals during the tuning process. I will analyse the tuning system that Santo Trunzo (born in 1930), *conflentana* and *surdulina* bagpiper from Nocera Terinese (in central Tyrrenhian Calabria), uses for his instruments. Audio example 1 is an excerpt of Santo Trunzo's *Ninna,* a *sunata* played for the Christmas celebrations and published in Bressi *et al.* 2017. This tuning system is also used by other *surdulina* players from the same and different areas – including myself – as well as by musicians who play pipes from different bagpipe families. I do not claim that the one I describe in this paper is *the* standard tuning system of surduline, or of any other Calabrian bagpipe. My intent is to offer a new

[1] An introductory literature on Calabrian bagpipes may include (Cravero 2006; Guizzi, Leydi 1985; Jensen, Andersen 1976; La Vena 1986, 2002, 2003, 2005; Leydi 1979; Guizzi 2002; Scaldaferri 1994, 2015; Tucci 2009; Staiti 2021a, 2021b)

analytical approach to the study of tuning that takes as a reference intervals that are easily recognised by ear. This approach could be applied to the study of other tuning systems found in Calabrian or in other Italian bagpipes, and even used to study the tuning of other instruments that produce multiple simultaneous sounds. The analyses presented here use a particular combination of methods including aural evaluation, ethnographic methods, psychoacoustics, sound recordings and computer-based pitch analysis. My analyses are grounded in strong ethnographic data and have the bagpiper's perception and evaluation of tuning as their starting point and prime focus. Furthermore, my study looks into the tuning method that the bagpiper adopts, and takes into account the technical features of the instrument that affect its tuning. Bagpipes are tuned by aurally evaluating dyads, triads or tetrads: in other words, each pitch is tuned against one to three simultaneous sounds. Tuning by triads and tetrads has an impact on the number of intervals that can be tuned by ear: it also links the tuning system to specific features of the instrument, especially to those pitches that can be played simultaneously, which are used as a reference when tuning the instrument.

First, I delineate my methodology and describe the approach I used to study Santo Trunzo's tuning process and system. I discuss Marc Sabat's concepts of "tuneable interval" and "fusion", as they will play an important role in my analyses. Then, I discuss some technical features of *surdulina* bagpipes. Rather than providing a detailed description of the instrument, this section examines only those features that affect the instrument's tuning: the single reed and its peculiar instability, the two melodic chanters of the same length, and the parallel position of the finger-holes along the chanters. I demonstrate how these properties are oriented by and influence cultural choices that emerge in the tuning process. I also reflect on how such a functional activity as tuning is governed by extremely refined musical processes. In the main body of the article, I describe Santo Trunzo's tuning process and analyse his tuning system: I present the ethnographic data and provide various analyses of his tuning produced by different analysis methods. I use auto-ethnographic data to double-check the results from Trunzo's analyses. Finally, I examine Agostino Troiano's recording published in La Vena (2002) to complement my analyses and to compare the Trunzo results to the tunings of a musician from a different area. Agostino Troiano (1912-1991) is a *surdulina* player from San Paolo Albanese, in Basilicata. His tuning system is shared by other *surdulina* players both from Basilicata and Calabria and it is used here as a cross-reference for the system that Trunzo uses.

Methodology: Aural evaluation, ethnographic data and pitch analysis

In this study, I use mixed methods of analysis, namely ethnography and auto-ethnography, psychoacoustics, aural evaluation and pitch analysis. The complexity of the task requires approaching the issue from different methodological points of view. However useful and in most cases accurate, computer-based analysis tends to lose accuracy when dealing with an instrument, such as the *surdulina*, that produces many simultaneous sounds that are close to each other and contained within an octave. Besides, pitch and spectral analysis only focuses on the physical aspects of sound and intervals and neglects the importance of how they are perceived. The machine cannot grasp the effects that sound produces within the ear and in the mind of the listener: it ignores the bodily implications and the perceptive effects of the diverse qualities of intervals. Perception plays a major role in discriminating the amplitude of intervals, especially when the ear and mind of the listener are dealing with the perception of simultaneous sounds (harmonic intervals). Simultaneous sounds trigger particular physical and perceptive responses, such as otoacoustic emissions, addition or subtraction tones, and – most importantly for the purpose of this study – the interval's perceived periodicity. The latter is especially important when tuning an instrument by ear and, as I will demonstrate, it appears to act as a reference for the bagpiper during the tuning process.

Giorgio Adamo (1996) recommends a dual approach to the study of pitch that takes into account both sound analysis and psychoacoustic models. He points out how, besides offering a more complete picture of the sound phenomena at hand, this approach makes it possible study an emic perspective of sound and music. Psychoacoustics studies sound in relation to the limits of human hearing, as well as the bodily and perceptive effects produced by sound (Fastl, Zwicker 2007). Drawing on psychoacoustic studies, Marc Sabat and Robin Hayward identify a series of intervals that they divide into three classes: «*tuneable* intervals which may be tuned precisely by ear; intervals which cannot be *directly* tuned but may be reached through a *finite series* of tuneable interval steps; and intervals which *cannot* be precisely tuned, even if they can be closely approximated by a trained listener» (Sabat, Hayward 2006: 1). Building on Helmholtz's (1954) work, Sabat and Hayward call a tuneable interval a "consonance" and an interval that cannot be precisely tuned a "dissonance". They note that:

> tuneability is not proposed as an absolute property. It varies depending on the register, relative volume and timbre of the sounds, as well as on the experience of the listener. Nevertheless, it suggests a precise perceptual definition of consonance: namely, *a consonant interval is one which may be precisely tuned by ear*. (*Ibidem*: 3)

They also

> distinguish tuneable intervals from intervals which may played by memorising their sound and approximating their size. There are many ratios which familiar usage allows us to play with acceptable accuracy, but it is not possible to say *from their sound alone* when they are exactly centred. (*Ibidem*)

Intervals that can be precisely tuned by ear produce particular perceptive effects, the most important of which is fusion. Fusion is the "perceptible periodicity" of a harmonic interval, the point at which beatings are no longer heard and the interval is perceived as a focused unity.

> Consider two pitches, melodically close to each other, sounding simultaneously. As they approach unison, we perceive amplitude modulation or beating which gradually slows down. At a certain point, this beating is replaced by a phenomenon of spectral fusion (perceptible periodicity), which may be likened to a focussing of the sound of the interval 1/1. (*Ibidem*)

Fusion is a characteristic of tuneable intervals with smaller harmonic ratios, and, because it is an inherent perceptive effect, is fundamental to my analyses.

Marc Sabat's empirical experimentations give a clear idea of the kind of intervals that can be perfectly tuned by ear, leaving others to approximations. As psychoacoustics attempts to understand sound from the standpoint of the perceiver, it could be easily inferred that the three categories of intervals Sabat proposes may apply to bagpipers as well. Bagpipers' ears are highly specialised in recognising the characteristics and qualities of the intervals on their bagpipes. Therefore, they must rely on a process of evaluation that takes into account the perceived periodicity of some harmonic intervals, even if to depart from it. When tuning their instruments, bagpipers rely only on their ear: they use no tools or external reference. They attempt to match the instrument's tuning to an image of sound that has been internalised throughout their training and perfected during a lifetime of practice. This method grants the ear a primacy that needs to be accounted for when attempting to grasp the way bagpipers achieve their desired tuning. True to the bagpipers' aural approach, I have adopted aural evaluation as my primary method of analysis. To do so, I had to train my ear to recognise the different qualities of harmonic intervals: I did so during a semester I spent researching with Marc Sabat in Berlin.

Being focused on the bagpiper's approach to tuning, this study uses abundant ethnographic data I collected throughout years of proximity to Santo Trunzo. I interviewed Santo Trunzo on many occasions and observed innumerable tuning sessions. He guided my training as a bagpiper and was a constant reference in my research. The recordings used in this article were taken on 24th August 2019. On that occasion, I asked him to show and explain his tuning process as if I were a novice. He did so by using a small *conflentana* bagpipe: the chanters are 30 cm long and the instrument's tone-centre is around B2. It is the smallest model that Erminio Mastroianni, bagpipe-maker from Nocera Terinese, builds.

As I am a member of the Calabrian community of folk musicians, auto-ethnographic methods (Ellis *et al.* 2011) will support the analysis both of relevant cultural artefacts and the information collected through interviewing cultural members. I started playing bagpipes in my late teens by following Santo Trunzo (among other bagpipers in the area) and learning in the traditional way, by imitation. In our meetings, Santo dwelled mainly on the process of *'ncannare* – making the reeds and matching them to the instrument – and on tuning the instrument. Less attention was paid to the repertoire, given that I was to learn it by imitation. I learnt to tune my bagpipes to the same tuning system that Santo Trunzo uses for his. Being trusted to tune his instrument confirms that I internalised his system. Bagpipers rarely allow other musicians to alter the tuning of their instrument: when pipers allow somebody to play their instrument, a usual warning is "not to mess with the tuning". My training in intonation with Santo Trunzo and Marc Sabat guided the analyses of tuning I conducted in this research. For these reasons, my methodology relies also on my personal experience, practice and skills as a bagpipe player which will support the analyses discussed in this article.

An aural evaluation of the intervals lies at the core of my analyses: first I try to identify the quality of the intervals by ear, listening to Santo Trunzo's bagpipes (both live and recorded). Afterwards, I recreate the intervals using sound generating software. I match the electronic sounds to the recordings and double-check the frequencies and their ratios. For this task, I use the 31-Limit Helmholtz-Ellis Calculator, «an accidentals and ratios to cents additive synth for microtonal MIDI playback» developed in Max MSP by Marc Sabat.[2] This tool allows custom pitches to be assigned to every key of a virtual or physical midi keyboard. These pitches can be assigned pre-set deviations – such as syntonic comma, Pythagorean comma, etc. – as well as custom assignments: the latter are calculated either as deviations in cents from the corresponding tempered pitch or by directly assigning a desired frequency to a specific key of the keyboard. Using this software, I can check the frequency ratios when the intervals produced with the Calculator match the recordings. Through the Calculator, I can also recreate what I deem to be a good tuning for my bagpipes by shifting the generated sounds up and down. This also allows me to check the frequency ratios of my desired tuning and match them to the outcomes of the analyses conducted on the recordings. At the end of this aurally guided process, I use computer-based spectral and pitch analyses to triple-check my readings and provide an "objective" assessment. I conduct pitch analyses with Sonic Visualiser (Cannam et al. 2010), a software tool developed in the Centre for Digital Music at Queen Mary, University of London.[3] Although this software is extremely reliable, the range of the bagpipes, contained within one octave, together with the simultaneous and uninterrupted sound production of the four pipes, produces a very rich spectrum that poses serious issues when using computer-based analysis. Nonetheless, the use of this software complements the aural analyses and reinforces my methodology.

My methodology is strongly influenced by my practice as a musician, both as a traditionally trained bagpiper and a western trained musician and composer. I work at the intersection of ethnographic and artistic practice (Stella 2009) and the cross-disciplinary approach I used provides valuable contributions to the field of ethnomusicology in unex-

[2] The software is freely available from Marc Sabat's website: <www.marcsabat.com>.

[3] As reported on the Sonic Visualiser's website, «the software is designed for musicologists, archivists, signal-processing researchers, and anyone else looking for a friendly way to look at what lies inside the audio file». This software is freely available at <https://www.sonicvisualiser.org/>.

pected ways. Working at the intersection of ethnographic and artistic practice is proving particularly fruitful as it offers new opportunities to communicate ethnographic research with the public (Scaldaferri 2016; 2017). In addition, working with what Clifford Geertz calls "blurred genres" allows researchers to explore new forms of representation of the phenomena at hand, thus offering unprecedented opportunities for a better understanding (Geertz 1983). My analyses of bagpipe's tuning started when the I encountered the music of James Tenney and in particular his string quartet in just intonation *Koan* (1984). In the ever-shifting harmonies of this fantastic piece, I could hear some of the qualities of intervals with which I was familiar from my bagpipes. The encounter with *Koan* opened a new area of artistic investigation that brought me to Berlin to study intonation and just intonation composition with Marc Sabat, who had been a pupil of James Tenney's. These studies led to the analyses presented in this paper and eventually informed my composition of two string quartets that explore the tuning process and system of the *surdulina* bagpipes. These pieces explore an unrationalised harmonic space that is slowly pushed towards rationalisation, much like the way bagpipers correct the tuning of their instrument towards what they deem correct. For my study of tuning, the special intersections of ethnographic studies and composition proved particularly fruitful. The analyses benefited from compositional resources such as Sabat's studies, which are primarily intended for contemporary music practice. The analyses, in return, informed the creation of contemporary music, as they were primarily driven by creative needs. These intersections proved valuable for ethnomusicology and composition in respect of the specific idiosyncrasies of both disciplines, and hopefully contributed to providing new insights in the study of tuning.

The instrument and the acoustical properties of the single reed

Before dwelling on the analysis of the tuning system, I discuss some aspects of the bagpipes that play a major role in its tuning. Here, I provide a brief description of the *surdulina*, to give a basic introduction to readers who have never encountered this instrument. For those who wish to know more about Italian bagpipes, and the *surdulina* in particular, there is a vast and thorough literature , although this is mostly accessible to Italian readers.[4] This and the following sections focus especially on features that in one way or another influence the tuning of the instrument: from structural features, such as the single reed and the chanters of the same length, to cultural processes directly involved in the tuning process.

The *surdulina*, found in central to northern Calabria and the southern part of Basilicata, is a single-reed instrument whose chanters have cylindrical bores. The instrument is

[4] For a detailed examination of this instrument, see for instance (Guizzi, Leydi 1980, 1985; La Vena 1986, 2002, 2003, 2005; Guizzi 2002)

composed of two melodic chanters of the same length, and two drones (sometimes three). Each of the four (rarely five) pipes mounts a single and idioglot reed which is cut from top to bottom out of a piece of cane Arundo Donax (L). *Surduline* are characterised by the occlusion of the left-hand chanter at the distal end (the end furthest away from the body): this feature allows the piper to interrupt the sound when closing the chanter's four finger-holes. The performing technique alternates the closed holes with fingered positions, thus allowing the pipers to play staccato and rests. There are four morphological variants of the instrument, found in corresponding geographic areas and classified as follows: *surdulina di I tipo* (of the 1st kind), *surdulina di II tipo* (of the 2nd kind), *conflentana* and *stifetta* (La Vena 1986). Despite the morphological and acoustical differences among the four types (see, for instance, La Vena 1986, 2002, 2003, 2005), all variants produce a similar scalar system which is contained within one octave: see Figure 1.

FIGURE 1. Scalar system of the *surdulina* bagpipe.

The right chanter has four finger-holes plus one or two tuning holes (depending on the instrument's dimensions and type); the left chanter has four finger-holes. In the smaller versions of these bagpipes (such as surduline di I and II tipo), the holes are placed perfectly parallel, from top to bottom, along the two chanters. In bigger instruments such as the *conflentana*, the left chanter's finger-holes are shifted down by one or two holes depending on the dimensions of the pipes. Figure 2 shows a *surdulina* di II tipo and the parallel position of its finger-holes.

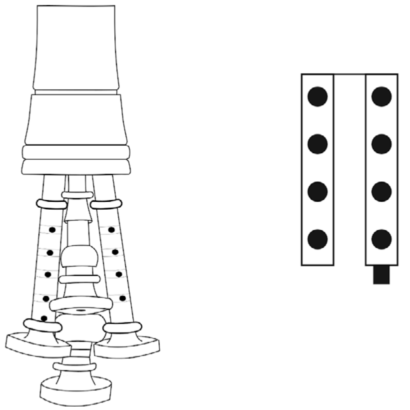

FIGURE 2. *Surdulina* of the 2nd type and parallel position of the finger-holes.

The most important features for the purpose of this study are the single reed, the two chanters of the same length and the parallel position of the finger-holes along the two chanters. These features are intertwined and co-dependent. The single reed allows considerable control over the acoustic properties of a sounding pipe. This device allows the piper to shift the tone-centre of a pipe up or down, thus making it possible for two pipes of the same length and with parallel finger-holes to produce different pitches. In a reed instrument, sound is produced by the cyclical interruption of the airstream passing through the lamella. The air passes through and creates a pressure differential that pushes the lamella down and closes the reed. The sound wave travels to the distal end of the pipe and flows back to open the reed once again. New air then enters, and a new interruptive cycle is started. Single reeds allow a great variability of the duration of their interruptive cycle: the phase in which the airflow goes through the reed (which depends mainly on the reed's characteristics) can be slowed down in various ways, the simplest of which is by making the lamella heavier by applying some beeswax on it (La Vena 2005). Another way to make the lamella heavier is to cut it longer, although this also weakens the elasticity of the fibres, resulting in a less responsive reed. The morphology of the *surdulina*, with their two melodic chanters of the same length and the parallel position of the finger-holes along the two chanters, entirely relies on this characteristic of the single reed. When preparing the reeds for their instrument (pipers use the term *'ncannare*, literally "to put the cane"), pipers choose their reeds and manipulate them so that the bagpipes can produce the desired sets of pitches and be properly tuned. This preliminary operation is fundamental to identify the desired tone-centre and sound quality of the instrument, and lays the ground for the actual tuning process.

Even after the instrument has been properly tuned, adjustments are required. Temperature and humidity have a decisive effect on the tuning of the instrument, which has to be perfected at the beginning of each performance. Humidity infiltrates the reed's fibres, making the lamella heavier; temperature influences the airspeed in the pipes, affecting the pitches they produce. The instrument needs to be warmed up for a certain time before it can properly and steadily play in tune. *'Ncannare* and tuning the bagpipes are time-consuming tasks that involve specialised knowledge as well as highly developed practical and aural skills that are normally acquired by the experienced piper through a long empirical training period. These skills are often acquired through the use of propaedeutic instruments such as the cane double clarinet, a simple instrument that pipers make themselves, which reproduces the physics, acoustics and fingering of the bagpipes on a small scale (La Vena 2009).

The process of manipulating the acoustic properties of a sounding pipe is structural to all the single-reed bagpipes in Calabria although it is particularly evident in the surduline of the 1st and 2nd kind. In these instruments the finger-holes of the two chanters are perfectly parallel from top to bottom: two parallel holes on the right and left chanters produce sounds that are a fourth apart. It is also a key feature of bigger instruments, such as the *conflentana*, where parallel finger-holes produce sounds that are a third or a second apart, depending on the dimensions of the instrument. Forcing the tuning is also observable in other bagpipes featuring chanters of the same length, such as the *zampogna a paro*, and plays an important role in the left chanter of the *zampogna a moderna*, allowing it to reproduce the scalar system of the *zampogna a chiave* without recurring to the fifth-finger key.

The cultural component of the tuning process

Manipulating the tone-centre of a sounding pipe is not done because of a lack of understanding of the acoustical properties of a reed instrument, nor as a consequence of the rudimentary technology used in the construction process. Bagpipers and pipe-makers are well aware of the acoustic properties of their instruments and of the materials at hand. They know that a low tone-centre can be easily achieved by using longer pipes. In the *surdulina*, instead, that goal is sought regardless of the dimensions of the instrument. It appears that pipers force the tone-centre of their instruments as part of a clear aesthetic and cultural choice, made possible by a profound understanding of the acoustics of a sounding pipe. The cultural component of tuning lies, therefore, in the very morphology of the instrument, in the adoption of chanters of the same length. Cultural choices concerning tuning emerge also in the choice of the instrument's tone-centre and in the tuning process. The tone-centre is not forced only in the left chanter in order to make it sound lower than the right despite having the same length. The process described above is applied to the entire instrument: the right chanter's tone-centre is often forced up or down in the first place, thus shifting the tuning of the whole instrument.[5]

As mentioned in the preceding section, *'ncannare* involves a highly specialised understanding of the acoustical properties of the instrument and of the materials used. Tuning the instrument too involves very refined technical expertise as well as sophisticated aural and musical skills. However, despite being considered neither a musical activity per se nor part of a performance, tuning is more than simply a functional activity. It is an essential part of the piper's musical resources; a culturally defined process that reveals extremely refined aesthetic choices. Manipulating the tone-centre of a sounding pipe allows a culturally and personally oriented idea of sound to emerge. It is in fact possible to identify geographical areas, or individual players, oriented towards a low or a high tone-centre. In the *conflentana* region, for instance, it is common to find instruments whose acoustical properties are drastically forced through the methods described earlier. Vincenzo La Vena describes short instruments that are tuned to a much lower tone-centre than longer ones: for instance, Natale Rotella's *conflentana* bagpipe, whose chanters are 34 cm long, is tuned in D♯2, much lower than conflentane with chanter length between 40 and 50 cm and whose tone-centres range between F♯2 and A♯2 (La Vena 2005: 142). Similarly, La

[5] Bagpipers refer to this shift as *accordatura fina* (high tuning) or *accordatura grossa* (low tuning) depending whether the tone-centre is shifted up or down (La Vena 2003: 10).

Vena identifies the opposite process in other *surdulina* regions, where the instruments' tone-centres are forced to produce higher pitches.

Tuning the instruments to a much lower tone-centre than the bagpipes' "natural" one without resorting to longer pipes reveals an approach to materials and technology that goes beyond mere functionality. Materials and acoustics are forced by a culturally informed process in the search for an equally culturally informed idea of sound. The pipers look for a specific timbre and a particular balance among the sounds produced by the instrument that are not achievable by building longer instruments. In fact, lowering the ideal tone-centre affects the tuning of the finger-holes, which must be narrowed progressively towards the distal end of the pipe with beeswax. Narrowing the diameter of the finger-holes lowers the pitch produced but also reduces the amount of air that escapes through them, resulting in quieter sounds. As a consequence, the higher notes of the bagpipe play louder while the lower ones are progressively fainter. The repertoire played on these instruments revolves around this peculiar (im-)balance in the acoustics of the instrument (Ferlaino 2017), revealing once more the cultural component of such features.

The procedures adopted for tuning the bagpipes are also informed by cultural factors. Differences in the tuning process emerge according to geographical area. Tuning is achieved through aural evaluation of the harmonic relationships between the pitches produced by the instrument. Pipers tune their instrument through dyads, triads and tetrads. My observations brought to light geographically defined differences in the choice of these intervallic relationships. For example, in the two defining areas of the *conflentana* and the *surdulina* of the 2nd kind, the starting point and constant reference throughout the whole tuning process are, respectively, the higher and lower drone. It is common for pipers belonging to the area of the *conflentana* to mute the lower drone and adopt the higher drone as a reference for fine tuning. The opposite is common to the area of the *surdulina* of the 2nd kind. Thus, it appears that tuning is not merely a functional activity for getting the instrument ready to play. Tuning is, instead, a highly specialised, standardised and culturally defined process that requires refined musical skills. As such, it can be studied almost as a repertoire in its own right. Considering the high level of organisation and the outstanding aural skills involved, it appears evident that tuning the bagpipes requires very sophisticated musical abilities that only expert bagpipers possess. It is in fact common to find bagpipers who are able to play the instrument but do not possess the ability required by *'ncannare* and are unable to fine-tune their instruments.[6]

A final consideration regards the importance of a perfectly tuned instrument for the accomplished bagpiper. The instrument needs to be played for a certain time before it can properly and steadily play in tune. This is a time-consuming task and an integral part of the piper's repertoire. Many bagpipers refuse to play music until they are completely

6 Less expert bagpipers often turn to experts to have their instrument prepared and tuned.

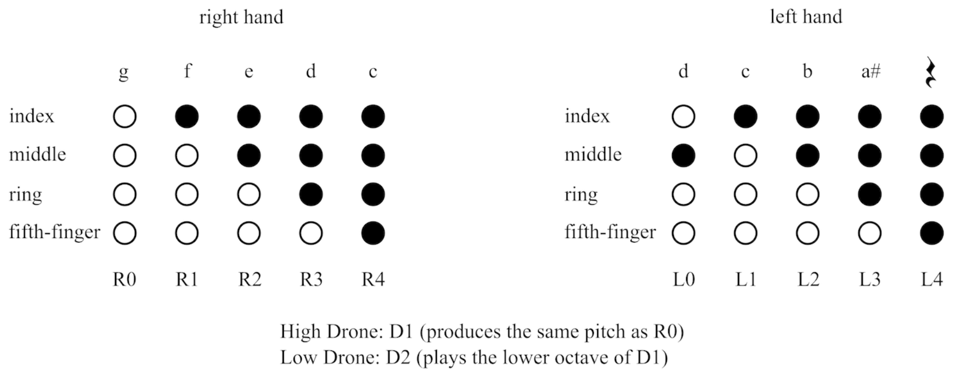

FIGURE 3. Labels of the fingerings used in the analyses.

satisfied with the tuning of their instruments. This could also mean making the dancers wait for minutes – sometimes over half an hour – until the piper is completely satisfied and ready to play.

Case studies: Tuning process and analysis

In the preceding sections, I discussed the cultural and technical factors that play a role in tuning the bagpipes. In this section, I describe the tuning process that Santo Trunzo adopts for his bagpipes, and I analyse his tuning. I analyse my own tuning and cross check the results with the analyses of a recording of Agostino Troiano.

Figure 3 shows a schematic overview of the fingerings along the two chanters and the pitches produced by a hypothetical *surdulina* with tone-centre in C. Each pipe and each fingered position is labelled – specified with letters and numbers at the bottom of the image. I will refer to these labels during my analyses: R0 is the highest pitch produced by opening all the finger-holes of the right chanter; R1 is the pitch produced by closing the top finger-hole on the right chanter and so on. D1 and D2 refer to the pitches produced by the drones (Fig. 3).

The tuning process starts with matching D1, R0 and D2. In the recordings I took on 24th August 2019, Santo Trunzo begins by matching R0 with D2, which are an octave apart. He then tunes D1, which plays in unison with R0. On other occasions, I observed Santo matching the unison D1/R0 first, before tuning D2. Either way, the two drones and the open right chanter are matched first. R0 is the reference tone for the instrument's tuning; its pitch is chosen when putting new reeds to the bagpipes. D1 and D2 have a telescopic section that allows the piper to shift their pitch up and down to match R0. Once these three sounds are perfectly tuned and produce no beatings, they become the reference tone for tuning the finger-holes of the entire instrument.

Having tuned the reference tones, Santo Trunzo moves on to fine tuning those finger-holes of the right chanter that produce intervals of fifths and fourths with the lower drone: R3 and R4. Then he tunes the corresponding pitches on the left chanter, L0 and L1, which produce the same pitches as R3 and R4 respectively. Bagpipers assess the corrections to be made by sliding the finger across the finger-hole: the partial and progressive closing of the hole results in a glissando that allows the bagpiper to estimate of the amount of wax that has to be inserted in the finger-hole to bring it to the desired tuning. When a finger-hole is too narrow, and thus its sound is too low, the corrections are assessed by progressively opening the finger-hole immediately above it, to assess the amount of wax that needs to be taken out. The next finger-hole that Santo tunes is R2. He evaluates this pitch against the drones and then double checks it with the tetrad D1/R2/L1/D2. L2 is tuned next; Santo evaluates the tuning of this finger-hole with the tetrad D1/R3/L2/D2. The last finger-hole that Santo tunes is R1: he evaluates the pitch of this finger-hole with the tetrad D1/R1/L0/D2.

Santo does not fine-tune L3, although he often puts some wax in the finger-hole in order to easily adjust the holes above – a small change to L3 produces a response on L2 and also on L1, though slightly less. The note produced by L3 is considered less harmonically significant in the *conflentana* region than in the regions of the *surdulina* of the 1st and 2nd type. Because of the very low tuning commonly found in the *conflentana*, the note that L3 produces is particularly faint and it is used mostly as an embellishment. In other areas, L3 has a much louder sound and it is given a harmonic-melodic function. Figure 4 summarises the sequences of fingerings that Santo uses to tune his instrument.

D2/R0	D1/R4/L1/D2
D1/R0/D2	D1/R2/D2
D1/R3/D2	D1/R2/L1/D2
D1/R4/D2	D1/R3/L2/D2
D1/R3/L0/D2	

FIGURE 4. Sequence of fingerings that Santo Trunzo uses to assess the tuning of his instrument.

The tuning of each pitch of the bagpipes is always achieved harmonically and never melodically. This process relies entirely on interactions between at least two, and up to four, sounds at the same time. Relations between two or more pitches can be expressed with frequency ratios. Marc Sabat notes that «there is a perceptual identity between intervals having the same *frequency ratio* because of the analogy between their composite vibration patterns and their composite spectral structures» (Sabat, Hayward 2006: 2). In other words, intervals with the same frequency ratio always produce the same perceptual effect, regardless of the specific pitches producing that interval. Marc Sabat also affirms that «when a sound exhibits a periodic or near-periodic pattern of vibrations, its spectral structure resembles a harmonic series, consisting of integer multiples of a fundamental frequency» (*ibidem*: 2). He also notes that «if a frequency ratio is represented by a ratio of natural numbers, the composite sound is also harmonic and is called a *natural interval*» (*ibidem*). These types of harmonic relations can be expressed through ratios of integer numbers, in which each number represents the position of the pitch on the harmonic series of a hypothetical common fundamental. For example, given two frequencies *f1*= 440Hz and *f2*= 550Hz, the interval *f2/f1* is expressed by the ratio 5/4. In this example *f2* can be regarded as the fifth harmonic of the fundamental *f0*=110Hz, and *f1* can be regarded as the fourth harmonic of the same fundamental, which would be the same tone two octaves higher. The relation 5/4 defines the natural major third interval. All the natural intervals that are found in the harmonic series can be expressed in this way. For example: 2/1 describe the octave; 3/2 the pure (Pythagorean) fifth; 4/3 the pure fourth (the inversion of a Pythagorean fifth) and so on. Ratios are also useful to express the different qualities of intervals, for instance different types of major third – such as 5/4 or 9/7 – or different types of minor third – such as 7/6 or 6/5. Ratios can also be used to describe the harmonic relations between more than two pitches by adding more factors to the fraction.

Santo affirms that a note is in tune when «you hear no more beatings» (*un vavulìe cchjù*) and the sound of the interval «becomes one» (*divente 'na cosa sula*). His words seem to recall Marc Sabat's concept of fusion with astounding precision. Marc Sabat and Robin Hayward (2006) define fusion as the «perceptible periodicity» of a harmonic interval, the point where beatings are no longer heard and the interval is perceived as a focused unity (Sabat, Hayward 2006). The authors also note that «any interval that may be determined by ear in a similar manner is called a *tuneable interval*» (*ibidem*: 3). Intervals that are tuneable by ear are called "consonances" and their frequency ratios are usually made up of smaller numbers. Santo Trunzo seems to possess empiric knowledge of fusion as he looks for this perceptive effect when tuning his instrument. As he looks for the fusion effect, Santo seems to rely on clearly recognisable intervals that are tuneable by ear – Marc Sabat's consonances. Thus, to understand Santo's tuning I must look into these types of harmonic relations.

I started my analysis of Santo's tuning system by aurally evaluating the quality of the intervals he uses. After tuning the unisons and octaves D1/L0/D2, Santo tunes the fifths so that this interval produces no beatings. In these intervals one can easily recognise the fusion effect of the natural harmonic fifth. Both D1/R3/D2 and D1/R4/D3 are tuned with Pythagorean fifths. The triad D1/R3/D2 produces a 4/3/2 interval; the triad D1/R4/D2 a 6/4/3 interval. Because R3=L0 and R4=L1, the same ratios apply to D1/L0/D2 and D1/L1/D2. To my ear, R2 sounding against the drones produces the fusion effect of the pure minor third 6/5. When Santo Trunzo tests it with the tetrad D1/R2/L1/D2, the resulting sound is that of a 6/5/4/3 interval. R2 is then in a 5/4 relation – a pure major third – with R4 and L1, the tone-centre of the bagpipes. I perceive a similar fusion effect in the tuning of L2. The tetrad D1/R3/L2/D2 produces the effect of an 8/6/5/4 ratio, where R3 is at a Pythagorean fourth with D1 and L2 is a pure major third above D2. This tetrad is a harmonic major triad with the lower drone as a fundamental, which is also doubled an octave above. The last tone that Santo tunes is L1. To my ear the interval he seeks produces the effect of the septimal minor third. The tetrad D1/R1/L0/D2 that he uses to assess the tuning results in an 8/7/6/4 ratio.

I verified my aural evaluations using the 31-Limit Helmholtz-Ellis Calculator. The Calculator allows custom pitches to be assigned to each key of a midi keyboard with extreme precision. This piece of software also allows harmonic intervals to be calculated by using pre-set interval deviations. It is possible to assign a pre-set deviation to a pitch to bring it precisely to the frequency of a chosen harmonic of a given fundamental: all the pre-set deviations are applied to Pythagorean fifths. To check my readings, I matched the sounds produced by Santo's bagpipe to those produced in the Calculator. However, there was a problem with Santo's recording. When a bagpipe has been inactive for a while in the torrid Calabrian summer temperature, as Santo's had been, the tone-centre changes as the instrument is being played. Changes in humidity produced by blowing into the instrument and changes in the air temperature within the pipes affect the general tuning of the bagpipes. Nevertheless, this did my analyses no harm, for two reasons. Santo tunes each pitch relationship separately and tells me when it is in tune. Thus, the tuning of each relationship is achieved regardless of the general pitch of the bagpipe changing over time. Furthermore, I can use the *kammertone* slider of the Calculator to slide all the pitches of the keyboard up or down without having to reassign new pitches to each key or recalibrate the calculated harmonic relations.

I tuned the C♯ and B keys to produce Pythagorean fifths above and below the *kammertone* F♯. The sound produced by these two frequencies perfectly matches the quality of Santo's fifths. The frequencies obtained in this reading are: D1/R3 = 262,2095Hz / 271,6571Hz; D1/R4 = 360,09Hz / 240,06Hz. I then tuned the other pitches until the quality of the intervals produced by the Calculator perfectly matched Santo's tuning. For instance, the frequencies returned by D1/R2 are 359,4881Hz / 299,5734Hz, which results in 1,2000000667616017, a pretty close approximation to 1,2 (6/5). I repeated this procedure for all the tones that Santo Trunzo uses for fine tuning his bagpipes. Audio examples 2-4 are comparisons of Santo Trunzo's tuning against the one reproduced in the 31-Limit Calculator (Audio example 2 shows the harmonic relation D1/R3/D2; Audio example 3 shows the relation D1/R2/L1/D2; Audio example 4 shows the relation D1/R1/L0/D2. The intervals calculated with the 31-Limit Calculator matched the aural evaluations I had done previously: the analysis returned the same frequency ratios I had predicted. These are summarised in Figure 5:

Fingerings	Frequencies	Ratios
D1/R3/D2	362,2095 / 271,6571 / 181,1047	4/3/2
D1/R4/D	360,09 / 240,06 / 180,045	6/4/3
D1/R2/L1/D2	363,9675 / 303,3062 / 242,645 / 181,9837	6/5/4/3
D1/R3/L2/D2	361,2503 / 270,9399 / 225,7832 / 180,6266	8/6/5/4
D1/R1/L0/D2	359,655 / 314,6981 / 269,7515 / 179,8275	8/7/6/4

FIGURE 5. Results of the analysis of Santo Trunzo's bagpipe using 31-Limit Helmholtz-Ellis Calculator.

The last step of my analysis was to triple-check my readings with computer-based pitch and spectral analysis. For this task, I used the freeware Sonic Visualiser (Cannam et al. 2010). The range of the instrument, within one octave, together with the simultaneous and uninterrupted sound production of the four pipes produce a very rich spectrum that poses issues when using computer-based analysis. The readings with Sonic Visualiser, however precise, are not enough to explain a process that is entirely guided by the bagpiper's ear. This method is used here as an "objective" analysis intended to further test the ear-based analyses that are central to the purpose of this paper. The readings obtained with Sonic Visualiser confirm the results of both aural evaluations.

For the purpose of this study, it was useful to compare the results of Santo Trunzo's tuning with an analysis of my bagpipes. Santo trusts my tuning skills so much that, when we perform together, he sometimes asks me to fine-tune his own instrument when he feels too tired to do it himself. As I have internalised Trunzo's tuning, the analyses of my tuning should produce the same results in terms of harmonic ratios. For this analysis, I proceeded in two steps. The first step consisted in tuning and recording my own bagpipes. I then applied the same method I used for Santo's bagpipes and analysed it with both Sonic Visualiser and the 31-Limit Calculator. The second step was to reproduce in the 31-Limit Helmholtz-Ellis Calculator what I considered to be a satisfactory tuning for my bagpipes. All types of analyses returned ratios absolutely consistent with those described for Santo's bagpipes. Figure 6 shows the results of the tuning I obtained with the 31-Limit Calculator. Having listened to many *surdulina* players, I attempted also to tune L3 to what seemed to my ear to be an appropriate tuning for that finger-hole. Calculating the ratios, these results match the results presented in Figure 5; Audio example 5 is a recording of the tuning of various harmonic relations I obtained in the 31-Limit Calculator (D1/R1/L0/D2; D1/R3/L3/D2; D1/R3/L2/D2; D1/R2/L1/D2).

D1=R0 = 392,42Hz	R4=L1 = 261,6255Hz
R1 = 343,409Hz	L2 = 245,272Hz
R2 = 327,05Hz	L3 = 228,9384Hz
R3=L0 = 294,3287Hz	D2 = 196,21Hz

FIGURE 6. Results of the reproduction of my bagpipe's tuning in the 31-Limit Helmholtz-Ellis Calculator.

The last step of my analyses was to check the tuning of L3 and verify whether other musicians adopt a similar tuning system. In the *conflentana* region, the note produced by L3 is used primarily as an embellishment, played too quickly for its tuning to be understood. Santo accords little importance to the tuning of this note, both for this reason and also because of the very faint sound it produces on most *conflentana* instruments. However, I had recognised the tuning system described in this paper in various recordings of *surdulina* players. In some *sunate* found in the northern area of the *surdulina* (Southern

Basilicata and northern Calabria), L3 is used more consistently.[7] I analysed the recordings of Agostino Troiano, a *surdulina* player from San Paolo Albanese in Basilicata, published in La Vena (2002), track 1.

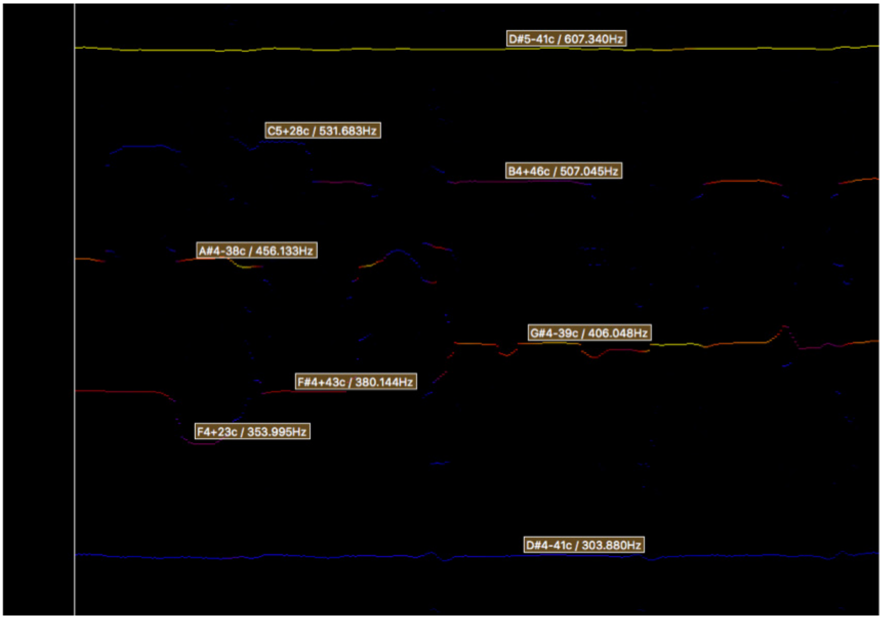

FIGURE 7. Sonic Visualiser snapshot of Agostino Troiano's tuning.

Aural analysis of L3 in this recording pointed towards a septimal sound. The combination D1/R3/L3/D2 in which that note usually appears has the sound of a 12/9/7/6 ratio: L3 seems to be tuned as the seventh harmonic of the tone-centre of the bagpipe. The analyses I conducted with the 31-Limit Calculator and with Sonic Visualiser returned similar results. The latter are presented in Figure 7, which shows a snapshot of the pitch layer in Sonic Visualiser: the text boxes show both frequency and pitch deviation in cents from the corresponding tempered ones. Figure 8 summarises the frequency readings obtained in Sonic Visualiser.

D1=R0 = 608,041Hz	R4=L1 = 405,584Hz
R1 = 531,782Hz	L2 = 379,957Hz
R2 = 507,182Hz	L3 = 354,717Hz
R3=L0 = 456,043Hz	D2 = 304,020Hz

FIGURE 8. Frequency readings in Sonic Visualiser of Agostino Troiano's tuning.

[7] Vincenzo La Vena (2002) uses the term *sonata* to translate the vernacular word *sunata*. This term is used in the region to refer to a piece of instrumental music, as well as to shorten the locution *sunata d'abbađđu* or *sunata ppe abbađđare,* which are used explicitly for dance music. I prefer using the vernacular word *sunata* to avoid any confusion to those readers for whom *sonata* may refer to the classical form of orchestral music.

A pattern emerges in the frequencies shown in Figure 8. Dividing each frequency by R4 – the tone-centre of the bagpipes – produces the results shown in Figure 9. The table shows the finger-hole reference, the factors of division expressed in frequency, the result and the closest ratio.

Finger-holes	Frequency 1 / Frequency 2	Result	Closest ratio
D1/R4	608,041Hz / 405,584Hz	1,4991	3/2 (=1,5)
R1/R4	531,782Hz / 405,584Hz	1,3111	21/16 (=1,3125)
R2/R4	507,182Hz / 405,584Hz	1,2504	5/4 (=1,25)
R3/R4	456,043Hz / 405,584Hz	1,1244	9/4 (=1,125)
L2/R4	379,957Hz / 405,584Hz	0,9368	15/16 (=0,9375)
L3/R4	354,717Hz / 405,584Hz	0,8745	7/8 (=0,875)
D2/R4	304,020Hz / 405,584Hz	0,7495	3/4 (=0,75)

FIGURE 9. Frequency relationships of each pitch with R4, results and closest ratio.

The rightmost column of Figure 9 shows that R4 is always a power of 2: that means that all the pitches in this tuning system belong to a harmonic series that has its fundamental on a lower octave of R4. Indeed, the pitches in this tuning system belong to a single harmonic series built on a common fundamental that is four octaves lower than the tone-centre and whose frequency is R4:16 = 25,349Hz. Simplifying the ratios to the minimum denominator of 2, Figure 9 can be re-written to show the simplest relation of each pitch to the fundamental, as they first appear in its harmonic series. Figure 10 shows more clearly that this tuning system is based on multiples of harmonic numbers 1, 3, 5, 7, 9, 15 and 21 of the bagpipes's tone-centre. These readings show that L3 is indeed the seventh harmonic of the tone-centre of the bagpipe and at a septimal third relation with the lower drone D2.

Position on the instrument	Position on the harmonic series	Simplified harmonic position
D1=R0	24	3
R1	21	21
R2	20	5
R3=L0	18	9
R4=L1	16	1
L2	15	15
L3	14	7
D2	12	3

FIGURE 10. Position of the pitches in the harmonic series and simplified harmonic numbers.

Figure 11 compares the ratios obtained with the results in the central column of Figure 10 with the combinations of pitches used to assess the tuning of the bagpipes reported in Figure 4. The left column gives the simplified ratios to the greatest common divisor. These ratios match perfectly the ones I used to describe Santo Trunzo's tuning.

Harmonic relations	Ratios	Simplified ratios
D1/R3/D2	24/18/12	4/3/2
D1/R4/D2	24/16/12	6/4/3
D1/R2/L1/D2	24/20/16/12	6/5/4/3
D1/R3/L2/D2	24/18/15/12	8/6/5/4
D1/R1/L0/D2	24/21/18/12	8/7/6/4

FIGURE 11. Absolute and simplified ratios of the harmonic relations used to assess the tuning.

The Helmholtz-Ellis Just Intonation (JI) Pitch Notation is a notation system that Marc Sabat (Sabat 2004; 2009) devised to notate natural intervals. In the following Figures, I use this system on a stave to show the harmonic relations described by the ratios in Figure 11. In this notation system, all notes without accidentals (or with standard sharps and flats) are tuned as Pythagorean fifths (pure fifths); all other accidentals define a given deviation from the corresponding Pythagorean pitch. The JI Pitch Notation consists of over 60 symbols arranged according to 10 orders of deviation. For my analysis, I need only two:

- ♮↓ Stands for a syntonic comma deviation from a Pythagorean 5th: it refers to the pure major third (harmonic number 5 of the overtone series).
- ↓ Stands for a septimal comma deviation from a Pythagorean 5th: it refers to harmonic number 7 of the overtone series.

Given C as a hypothetical tone-centre and using the Helmholtz-Ellis Just Intonation Pitch Notation, the notes in this tuning system can be transcribed as shown in Figure 12. Here, C and G are tuned as a pure Pythagorean fifth; E and B are lowered by a syntonic comma (which makes E a 5/4 ratio with C and B a 5/4 ratio with G); F and B♭ are lowered by a septimal comma, which makes F the seventh harmonic of G and B♭ the seventh harmonic of C.

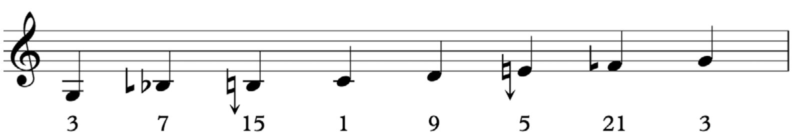

FIGURE 12. Transcription of the pitches in Helmholtz-Ellis Just Intonation Pitch Notation.

The pitch produced by the drones appears three times in the instrument: on D1, D2 and R0. This pitch is also ever present, as it is produced by the drones: this makes it a strong centre of harmonic attraction that competes with the tone-centre R4. The *surdulina* can thus be described as having two harmonic centres of attraction: the tone-centre and the drones. Some of the pitches in this tuning system are in a simple ratio relationship with both the tone-centre and the drone of the bagpipes. In fact, harmonic numbers 9, 15 and 21 sit on a harmonic series with base 3, meaning they sit on the harmonic series that has the drone as its fundamental. Thus, harmonic numbers 9, 15 and 21 of R4 are respectively harmonic numbers 3, 5 and 7 of D1. Because of the double nature of these notes, and considering the two centres of harmonic attraction of the instrument, the tuning system described here can be interpreted as being based on simple harmonic ratios of the two centres of attraction, C and G. Figure 13 shows how this tuning system can be interpreted as derived from the two centres of attraction. The black notes refer to pitches that belong to the harmonic series of R4; the blue ones belong to the harmonic series of D2. This interpretation shows a tuning system constructed through the superimposition of the odd partials 1, 3, 5, 7 (more precisely, of multiples of the odd partials) of two harmonic series that are a fifth apart. It is then possible to interpret the tuning as the superimposition of two natural major septimal tetrads constructed on the tone-centre and on the drones of the *surdulina* bagpipe.

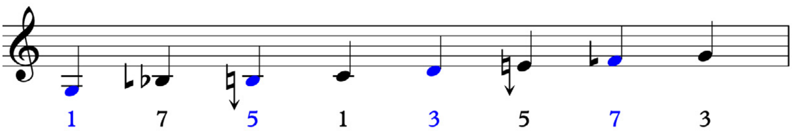

FIGURE 13. Simplified position of the pitches on the harmonic series of R4 and D2 using the Helmholtz-Ellis Just Intonation Pitch Notation.

A final consideration regards the analysis of this tuning system within the framework of the tempered scale. Figure 14 shows the outcomes of my analyses transcribed in traditional notation. I indicate the deviation of each pitch from the corresponding tempered ones in cents. This figure shows how every pitch of this tuning system, except the tone-centre, deviates somewhat from the corresponding tempered ones.

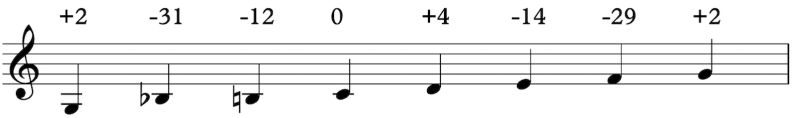

FIGURE 14. Pitches of the tuning system with deviation in cents from the tempered scale.

The deviations given here are quite noticeable by ear, even the smaller ones. It is quite easy to hear beatings when the fifths are even slightly off a pure Pythagorean tuning. Given that bagpipers look for specific perceptive effects when tuning, the tempered scale fails to approximate the points where these effects are clear and recognisable. Indeed, taking the tempered scale as a reference might make complex something that is actually quite simple, as it is based on simple harmonic ratios that are tuneable by ear and easily described by the harmonic series. As fusion is a clearly recognisable perceptive effect, ratios, or deviation from simple ratios, may be a better tool to describe other tuning systems that differ from the one described in this paper.

Conclusion

This paper proposes a new methodology for the study of bagpipe tuning systems. The methodology is grounded in psychoacoustic studies that show that intervals with simple ratios produce particular perceptive responses that make them tuneable by ear. It is possible to speculate that intervals that are precisely tuneable by ear may function as a sonic reference during the tuning process. In the particular case studies presented in this paper, the tuning system entirely relies on intervals with simple ratios as the bagpipers involved seem to aim at fusion effects while tuning their instruments. Using natural intervals as a reference may also be useful for tuning systems that depart from the fusion effect. Musicians may look for particular perceptive effects or for specific periodicities that may be described by more complex numbers or by precise approximations, much like Marc Sabat's dissonances. In this case, tuneable intervals may still work as a better reference than the tempered scale because of the clearly recognisable perceptive effects from which bagpipers may depart for their tuning.

Although specific to a single tuning system and focused on the *surdulina*, the work presented here can be used for studying the tuning of other types of bagpipes. Such a study would need to take into account the technical and acoustic features of the bagpipes under examination as well as the emic view of the bagpiper on tuning. For example, I am confident that the tuning system studied in this paper would not work on the *zampogna a chiave delle Serre*, owing to some peculiar features of this instrument. The drones of the *zampogna a chiave* are tuned by fifths, as they play the tone-centre and the fifth grade. Having the tone-centre continuously present would make it very difficult, and quite harsh-sounding, to tune the fourth grade as a septimal sound: that tone would fall in the region of another tuneable interval. I have not researched a chiave bagpipes in depth, and an analysis of their tuning is outside the scope of this paper; I am confident, though, that the methodology presented here would be helpful for an understanding of the tuning systems of those instruments too.

Audio examples

1. *Ninna*, performed by Santo Trunzo on a *zampogna conflentana*. [00:39]
Recorded by S. Trunzo in the late 1970s in Nocera Terinese (CZ). Excerpt of the file published in Bressi et al. 2017, kindly provided by Giuseppe Muraca.

2-4. Comparison of the Santo Trunzo's tuning in the original recordings against the author's analyses in the 31-Limit Calculator. [00:24]
Original recordings by C. Ferlaino, Nocera Terinese (CZ), 24th August 2019.
2. Analysis of the relations D1/R3/D2. **3.** Analysis of the relations D1/R2/L1/D2. **4.** Analysis of the relations D1/R1/L0/D2.

5. Bagpipe's tuning reproduced in 31-Limit Calculator. [00:34]
Harmonic relations: D1/R1/L0/D2; D1/R3/L3/D2; D1/R3/L2/D2; D1/R2/L1/D2.
Tuning obtained by C. Ferlaino in the 31-Limit Calculator.

References

Adamo, Giorgio.
1996 *Analisi del suono e modelli psicoacustici nella ricerca musicologica*, Rome, Ministero per i Beni Culturali e Ambientali - Ufficio Centrale per i Beni Librari le Istituzioni Culturali e l'Editoria - Discoteca di Stato.

Bressi, Alessio, Giancarlo Di Toma, Christian Ferlaino, and Gianpiero Nitti
2017 *Musiche tradizionali nell'area del Reventino-Savuto*, 1 CD with booklet, F&C 001.

Cannam, Chris, Christian Landone, and Mark Sandler
2010 "Sonic Visualiser: An Open Source Application for Viewing, Analysing, and Annotating Music Audio Files", in *Proceedings of the ACM International Conference on Multimedia*, October 2010, Florence, Italy: 1467-1468.

Cravero, Chiara
2006 *Zampogne in Aspromonte*, Rome, Squilibri.

Ellis, Carolyn, Tony E. Adams, and Arthur P. Bochner
2011 "Autoethnography: An Overview", *Historical Social Research/Historische Sozialforschung*, XXXVI/4 (138): 273-290.

Fastl, Hugo and Eberhard Zwicker
2007 *Psychoacoustics. Facts and Models*, 3rd ed., New York, Springer.

Ferlaino, Christian
2017 *La musica da danza nell'area di influenza della Madonna di Conflenti*, Soveria Mannelli, Rubbettino.

Geertz, Clifford
1983 *Local Knowledge. Further Essays in Interpretative Anthropology*, New York, Basic Books.

Guizzi, Febo
2002 *Gli strumenti della musica popolare in Italia*, Lucca, LIM.

Guizzi, Febo and Roberto Leydi
1980 *Zampogne*, Milano, Albatros.
1985 *Le zampogne in Italia*, Milano, Ricordi.

Helmholtz, Hermann L. F.
1954 *On the Sensations of Tone as a Physiological Basis for the Theory of Music*, edited by Alexander J. Ellis, New York, Dover (1st German edition 1863-1877).

Jensen, Sverre and Terje Richter Andersen
1976 "An Unusual Italian Bagpipe", *The Galpin Society Journal*, XXIX: 112-115.

La Vena, Vincenzo
1986 "La zampogna nella Calabria settentrionale", *Preprint* 6, Bologna, Università degli Studi di Bologna - Dipartimento di Musica e Spettacolo.
1994 "Zampogna e doppio flauto nel versante jonico reggino: tipologia e distribuzione geografica", in Piero Borzomati (ed.), *San Luca. Storia tradizioni società a 400 anni dalla fondazione*, Ardore Marina, Arti Grafiche Edizioni: 411-424.
2002 *La surdulina nell'area di influenza della festa della Madonna del Pollino*, Rossano, Il Cerchio.
2003 *La surdulina nell'area di influenza della festa della Madonna del Pettoruto*, Rossano, Il Cerchio.
2005 *La surdulina nella parte meridionale della sua area di diffusione*, Rossano, Il Cerchio.
2009 "Strumenti propedeutici alla surdulina. Doppi e tripli clarinetti nella Calabria settentrionale", in Leonardo Alario (ed.), *Cultura materiale, cultura immateriale e passione etnografica*, Soveria Mannelli, Rubbettino: 195-223.

Leydi, Roberto
1979 *La zampogna in Europa*, Como, C. Nani.

Ricci, Antonello and Roberta Tucci
2004 *La capra che suona*, Roma, Squilibri.

Sabat, Marc
2004 "The Extended Helmholtz-Ellis JI Pitch Notation", online resource <http://www.marcsabat.com/pdfs/notation.pdf>.
2009 "An Informal Introduction to the Helmholtz-Ellis Accidentals", online resource <http://www.marcsabat.com/pdfs/legend.pdf>.

Sabat, Marc and Robin Hayward
2006 "Towards an Expanded Definition of Consonance", online resource <http://www.marcsabat.com/pdfs/tuneable-brass.pdf>.

Scaldaferri, Nicola
1994 "Appunti analitici sulla zampogna in Calabria", in Ignazio Macchiarella (ed.), *Fra oralità e scrittura*, Lamezia Terme, A.M.A. Calabria: 237-251.

2015 (ed.) *Le zampogne a Terranova di Pollino*, Roma, Squilibri.
2016 "Audiovisual Ethnography: New Paths for Research and Representation in Ethnomusicology", in Gianmario Borio (ed.), *Musical Listening in the Age of Technological Reproduction*, London, Taylor and Francis: 373-392.
2017 "(Absent) Authors, Texts and Technologies. Ethnographic Pathways and Compositional Practices", in Friedemann Sallis, Valentina Bertolani, Jan Burle, and Laura Zattra (eds.), *Live Electronic Music. Composition, Performance, Study*, London, Routledge: 217-229.

Staiti, Nico
2021a *"Ascoltate miei cari signori". Le musiche di tradizione orale in Italia*, Udine, Nota (with 2 CDs).
2021b *Tenui meditabor harundine. Tiritera su titiri, totare, tituelle, calamauli e cerauli*, Palermo, Edizioni Museo Pasqualino.

Stella, Maria Carmela
2009 *Pratiche artistiche e pratiche etnografiche,* Milano, CUEM.

Tenney, James
1984 *Koan*, Baltimore, Smith Publications.

Tucci, Roberta
2009 *Calabria 1. Strumenti*, Nardò, Besa.