Almost Forty Years of Splitting Keys – How I arrived *chez* Descartes

Christopher Stembridge

I first travelled to Italy in 1977 in order to attend Luigi Ferdinando Tagliavini's organ course in Pistoia. There I made the acquaintance of music by Ascanio Mayone (ca. 1565–1627). The same year I moved to Oxford where I happened to be living in the same street as the early instrument maker, Denzil Wraight. In the British Museum (where the British Library then was) I discovered Mayone's *Primo Libro di Diversi Capricci* (Naples 1603) and, after transcribing and getting to know this music, I was invited to make an edition of this work by Kenneth Gilbert who also later encouraged me to record it.[1] Mayone's publication is unusual in that it contains D# as well as E♭. Denzil Wraight made a harpsichord for me which is basically a reconstruction of the apparent original state of an anonymous Italian instrument in the Russell Collection in Edinburgh (see ill. 1).[2]

The new harpsichord attracted much attention and several other musicians commissioned similar instruments from Denzil. With a range from C/E broken octave to f"', there are five split keys – in addition to those of the broken octave – to give the extra chromatic notes (d#/e♭ and g#/a♭) in the central two-and-a-half octaves of the instrument (c–f"). The provision of such extra keys was a relatively common feature of Italian organs and harpsichords of the period. It was now possible to play music by Trabaci, Mayone, later Frescobaldi, and others, in the way that it was almost certainly conceived.

Continuing my work on Mayone whose *Secondo Libro di diversi Capricci* (Naples 1609) contains two pieces for 'il cimbalo cromatico', I then asked Denzil to make a "cimbalo cromatico", i.e. a 'real' chromatic harpsichord with nineteen keys to the octave. While there is considerable documentary evidence that

1 Ascanio Mayone, *Diversi capricci per sonare*, ed. Christopher Stembridge, Padua: Zanibon 1984; *Consonanze Stravaganti*: *musica napoletana per organo, cembalo e cembalo cromatico*, Christopher Stembridge, Ars Musici AM 1207–2 (1997).

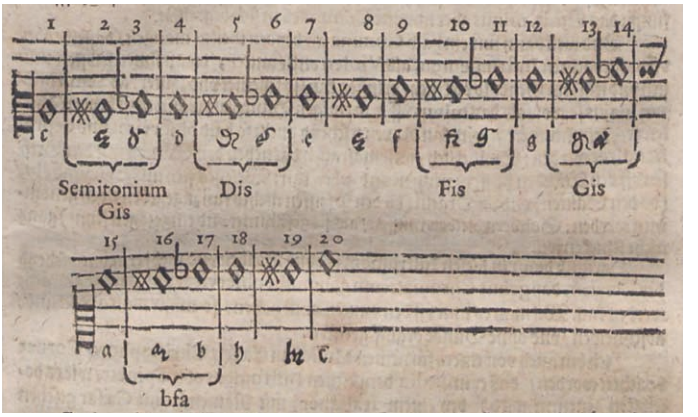
2 Edinburgh University Collection of Musical Instruments, inv. 4302. This instrument was made about 1620 and subsequently altered by Cristofori who removed the split keys and extended the range.

Ill. 1: Italian harpsichord with split keys made by Denzil Wraight, Oxford (1980).

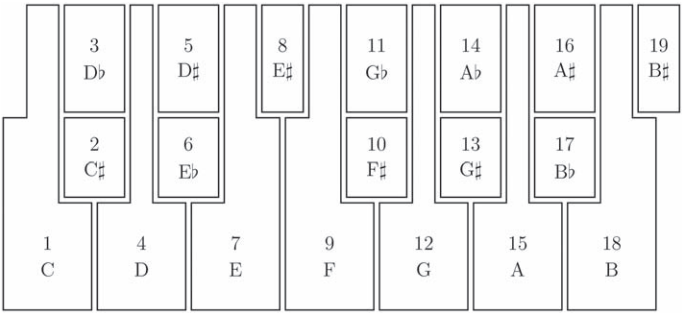
such instruments were by no means uncommon,[3] no such instrument of the period has survived in its original state. Of particular importance is the description of the "Clavicymbalum Vniversale" given by Michael Praetorius in volume two of his *Syntagma Musicum* (see ill. 2);[4] Denzil, whose profound knowledge of historic Italian keyboard instruments is probably second to none, made the new instrument in the Italian style of the period basing the keyboard on Praetorius and on the lower keyboard of Vicentino's archicembalo (see ill. 3). Vicen-

3 Trabaci writes a piece apparently for such an instrument but, as he explains, it cannot actually be played on it as he writes also e#; Giovanni Maria Trabaci, *Il Secondo Libro de Ricercate, & altri varij Capricci, Con Cento Versi sopra li Otto finali Ecclesiastici per rispondere in tutti i Diuini Officij, & in ogni altra sorte d'occasione*, Naples: Giovanni Giacomo Carlino 1615, 88–93. However Trabaci is pulling the wool over the reader's eyes, perhaps trying to impress the world that the 'cromatico' is insufficient and he has written for a more complicated 'cimbalo armonico'; the piece can be transposed down one tone and played quite satisfactorily on an ordinary *cimbalo cromatico*; see Christopher Stembridge "The 'Cimbalo cromatico' and Other Italian Keyboard Instruments with Nineteen or More Divisions to the Octave", in: *Performance Practice Review* 6/1 (1993), 33–59 <Open Access: https://scholarship.claremont.edu/ppr/vol6/iss1/ (7 August 2023)>: Appendix 2, 37–43 for the transposed version.

4 Michael Praetorius, *Syntagmatis Musici Tomus Secundus De Organographia*, Wolfenbüttel: Elias Holwein 1619, 63–66.



Ill. 2a: Representation of available pitches of the "Clavicymbalum Vniversale" in Michael Praetorius, *De Organographia* (Wolfenbüttel 1619), 65.



Ill. 2b: The same as set out as a drawing of the keyboard.

Ill. 3: *Cimbalo cromatico* made by Denzil Wraight, Cölbe-Schönstadt (1988); photo Denzil Wraight.

tino includes a plan drawing of his keyboards in his *L'antica musica ridotta alla moderna pratica* (Rome 1555) showing that they appear to have a short octave).[5]

While the bass octave is fully chromatic, since the short octave is required to make some music of the period playable, Denzil made a device that offers both possibilities. The five jacks that pluck to the right can play strings tuned to C, D/F# and E/G# instead of the jacks plucking to the left in the main register which play E, F#/G♭ and G#/A♭.

The specific solo repertoire for the *cimbalo cromatico* is limited enough to be able to be presented in a single programme;[6] but the harpsichord is of course of enormous use for playing continuo. But after a while the novelty of having a full vocabulary of perfect major thirds started to wear thin as I tired of being shut in a cage of such narrow (1/4 comma) fifths. The presence of a nineteen-note keyboard of course invites one to experiment with a circular temperament – not so easy to tune – so that all the intervals are equal. In theory one would not expect this to sound well since not only are diatonic semitones twice the size of chromatic ones (c–c#–d♭–d etc. consisting of equidistant steps), but the fifths are even narrower (1/3 comma) and, in addition, we have lost our pure major thirds which are now also 1/3 comma flat. Perhaps it is the fact that the fifths and major thirds are equally good – or equally bad – that makes this temperament acceptable, or perhaps it is the result of the minor thirds being virtually pure, although our ears are so unused to hearing pure minor thirds that they do not immediately appreciate such purity. This temperament is described 1577 by Francisco de Salinas in his *De Musica libri septem* who claims to have discovered it when in Rome when he was younger (i.e. 1537–1549).[7] Zarlino describes it as 'a bit more languid' than 1/4 comma or 2/7 comma meantone.[8]

5 Nicola Vicentino, *L'antica mvsica ridotta alla moderna practica*, Rome: Antonio Barrè 1555. While the layout of the bass octave corresponds to the normal broken short octave, the black keys which would normally play D and E are in fact labelled F# and G#; this is probably in error since the lowest (white) key should then be E but is not labelled and, as the first key of a short-octave layout, would appear to be C.

6 Christopher Stembridge, "Music for the 'Cimbalo cromatico' and Other Split-Keyed Instruments in Seventeenth-Century Italy", in: *Performance Practice Review* 5/1 (1992), 5–43 <Open Access: https://scholarship.claremont.edu/ppr/vol5/iss1/ (7 August 2023)>; idem, "The 'Cimbalo cromatico'"; Martin Kirnbauer, "Viele Tasten – viele Töne. Das Cimbalo cromatico und musikalische Praxis", in: Michael Kunkel (ed.), *les espaces sonores. Stimmungen, Klanganalysen, spektrale Musiken*, Büdingen: Pfau 2016, 43–57.

7 Francisco de Salinas, *De Musica libri septem*, Salamanca: Mathias Gastius 1577, 140.

8 Gioseffo Zarlino, *De Tvtte l'Opere […] Il Secondo Volvme. Contenente Le Dimostrationi Harmoniche*, Venice: Francesco de' Franceschi Senese 1589, 201 ("un poco più languido").

I found it more interesting and useful to tune the major thirds slightly wide of pure in order to improve the quality of the fifths. (In fact if we go so far as to tune them as 1/5 comma fifths – a temperament that was practised in 17th-century Italy, and possibly already by Lanfranco in 1533 – the thirds and fifths are also equally good and of course considerably better than in 1/3 comma temperament.)[9] When I tuned the harpsichord this way for a concert in Ferrara at the *Settimana Frescobaldi*, Denzil, who happened to be present, could not understand why, when he had provided me with all those chromatic semitones, I did not tune the major thirds pure. Apart from the fact that a single-strung instrument can often sound better if no intervals are 100% pure, it has to be said that, in addition to having rather better fifths, there was still a large difference between sharps and flats – even using 1/5 comma there is almost 30 cents between them. (Denzil is meanwhile tuning more Vallotti than meantone and is somewhat surprised at my recollection; he now certainly finds that good thirds do not have to be pure.) I have discussed the question of 'irregular' meantone tunings, for which there is plenty of evidence, elsewhere.[10]

I never met anyone who had a *cromatico*, though I think there were some around. I did visit the Germanisches Nationalmuseum in Nuremberg to see an instrument made by Franciscus Faber that was later altered but it is possible to see the traces in the key-frame of its original state.[11] While there I had the opportunity of playing on the copy they made there of the Bologna Trasuntino *Clavemusicum omnitonum*.[12] Since the front part of the keyboard is constructed like the *cromatico*, at least that part of the keyboard is playable. However the double sharps and double flats are less manageable. The logic is that where the front black key is a sharp and the second therefore a flat, the third is a double sharp and the fourth a double flat. They are the other way round where the front key is a flat. This means that the highest black key behind G# is A♭♭ while its neighbour, the highest one behind B♭, is A##. It is extremely difficult for the fingers to accept that two keys that feel as if they are one tone apart in

9 Lanfranco's description is imprecise but the major thirds were tempered; see Giovanni Maria Lanfranco, *Scintille di musica*, Brescia: Lodovico Britannico 1533, 132–136.

10 Christopher Stembridge, "Qual'è il temperamento dell'*Arte organica*? (Antegnati's proposed temperament not pure mean-tone?)", in: *Gli Antegnati: Studi e documenti su una stirpe di organari bresciani del Rinascimento*, Bologna: Patròn 1985, 25–28 and, idem, "Die mitteltönige Stimmung", in: Wolfram Steude and Hans-Günter Ottenberg (eds.), *Theatrum Instrumentorum Dresdense. Bericht über die Tagungen zu historischen Musikinstrumenten Dresden 1996, 1998 und 1999*, Schneverdingen: Wagner 2003 (Schriften zur Mitteldeutschen Musikgeschichte 11), 226–300.

11 Germanisches Nationalmuseum Nürnberg, inv. MIR 1072.

12 Germanisches Nationalmuseum Nürnberg, inv. MI 533.

fact play the interval of a minor third; the opposite occurs when playing A## together with Dbb.

At this time I also wrote a series of articles, the third one together with Denzil, on these instruments. These were published in *Performance Practice Review* 1992–94.[13]

Max Yount, an organist from Beloit College, Wisconsin, when playing in Marburg one summer, visited Denzil who acquainted him with my Mayone editions and recordings. Max subsequently invited me to give the keynote address at the Mid-West Historic Keyboard Society convention that was held in Beloit in 1997, ten years after my *cromatico* had been made. The idea was that I should talk about the chromatic harpsichord even though they did not have one in Beloit. But then two months before leaving for the USA, I received a telephone call from Willard Martin in Pennsylvania who said he had seen that I was coming to Beloit to talk about the *cromatico* and wanted to know whether, if he made such an instrument for the convention, I would be happy to play a recital on it. Of course I said I would but pointed out that it was only two months away. "No problem!" was his reply.

Wisconsin was a memorable event. The new *cromatico* was very comfortable to play; while not so specifically Italian it has a bigger range than Denzil's instrument since, in addition, it follows that described by Praetorius to the extent of having a keyboard that transposes to six different positions (Praetorius says seven in fact).[14] After the convention I travelled with Willard, via Oberlin and Cleveland, to his home and workshop in Bethlehem, PA. Willard was interested in placing the *cromatico* in the context of Italian Renaissance art and in Oberlin we were received by Richard Spear, the leading specialist on the painter Domenichino who made instruments including a chromatic harp and commissioned a chromatic harpsichord from Orazio Albani.[15] A chromatic harp features in his famous painting of David in Versailles (a painting that Willard knew from the years he lived and worked in Paris).[16] In Oberlin I also saw John

13 Stembridge, "Music for the 'Cimbalo cromatico'"; idem, "The 'Cimbalo cromatico'"; Denzil Wraight and Christopher Stembridge, "Italian Split-Keyed Instruments with Fewer than Nineteen Divisions to the Octave", in: *Performance Practice Review* 7/2 (1994), 150–181 <Open Access: https://scholarship.claremont.edu/ppr/vol7/iss2/ (7 August 2023)>.

14 Cf. Martin Kirnbauer, "Carl Luython and the 'Clavicymbalum Vniversale, seu perfectum' – Finding a historical and musical context. With an appendix on 'Vielhawer's tuning instruction' by Christopher Stembridge", in: *Clavibus Unitis* 10/3 (2021), 99–112 <Open Access: https://www.acecs.cz/index.php?f_idx=4&f_cu=cu_2021_10 (7. August 2023)>.

15 See Richard Spear, *Domenichino*, New Haven and London: Yale University Press 1982, 40–43.

16 Musée national des musées de Versailles et de Trianon, inv. MV5359.

Brombaugh's organ in the Fairchild chapel which has split keys, it was the first time I ever saw split chromatic keys in the pedals.[17] We also went to Princeton to visit Thomas Dacosta Kaufmann, the Arcimboldo specialist; the reason that Willard placed a reproduction of Arcimboldo's *Vertunno* (a portrait of the Emperor Rudolph II) on his harpsichord is that, not only was it in Prague that Praetorius saw the chromatic "Clavicymbalum Vniversale" which he describes, but Gregorio Comanini in his treatise *On the Purpose of Painting* (1591) claimed that Arcimboldo – employed at Rudolph's court in Prague – "located the tones, semitones, the diatesseron, the diapente, the diapason, and all the other musical consonances in colours".[18] (This is, of course, a rather tenuous connection and, rather ironically in the context of the *cromatico*, Comanini suggests that Arcimboldo was heading in the direction of equal temperament: "This ingenious painter was able not only to find these larger and smaller semi-tones in his colours, but also the division of the whole tone into two equal parts, so lightly and deftly did he darken the white, always little by little, gradually ascending to greater darkness, just as from a low note one moves gradually to a higher one and then on to an even higher one."[19])

Ill. 4: Keyboard of a harpsichord attributed to Giovanni Battista Boni da Cortona (c. 1619), olim private collection of Alexander Mackenzie of Ord (Bristol).

17 His 'Opus 25'. Cf. <https://www.oberlin.edu/conservatory/divisions/keyboard-studies/organ/fairchild (10.2.2021)>.

18 Gregorio Comanini, *Il Figino, overo del fine della pittvra*, Mantua: Francesco Osanna 1591, 244 ("il quale hà trouato i tuoni, e i semituoni, e'l diatesseron e'l diapente, e'l diapason, & tutte l'altre musicali consonanze dentro I colori").

19 Comanini, *Il Figino*, 245–246 ("questo ingegnosissimo pittore non solamente ha saputo ritrovare i detti semituoni maggiore e minore ne' suoi colori, ma la divisione ancora del tuono in due parti eguali, così leggiermente e dolcemente è ito offuscando col negro il bianco, sempre di grado in grado ascendendo a maggior negrezza, sì come dal suono grave si cresce di mano in mano all'acuto et al sopraacuto").

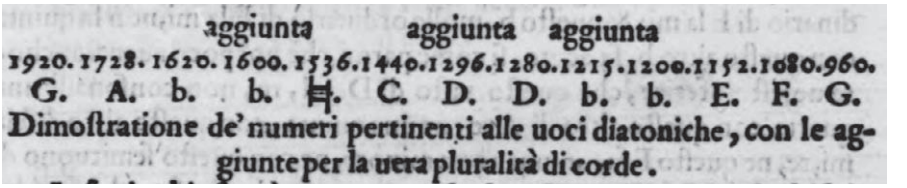
At this period I had the pleasure of playing and recording for the BBC several historic instruments with split keys; these included the organs in S. Petronio, Bologna (1471/1532) and Arezzo Cathedral (1536) and also a harpsichord attributed to Giovanni Battista Boni da Cortona (c. 1619) which has (in addition to the ubiquitous D#/Eb and G#/Ab) not only A#/Bb but also split natural keys in the bass (see ill. 4) the intended pitches of which continue to be discussed. This instrument belonged at the time to Alexander Mackenzie of Ord.[20] During this period I also helped make up a 'cembalino' designed and modified by Denzil with extra chromatic keys for use as a continuo instrument with the *Cappella Saggitariana*, a small ensemble in Dresden with whom I played regularly; the split keys gave us D#/Eb, G#/Ab and also A#/Bb (see ill. 5).

Ill. 5: Keyboard made by Denzil Wraight in 1992 for a modified version of the 'cembalino' designed by him in 1987 for the Early Music Shop, Bradford.

When I returned to the USA a year after Wisconsin, it was to hold a seminar on the *cromatico* together with Willard for New York City University. The following morning we discussed the possibility of creating a keyboard that would allow the possibility of having some pure fifths, developing the idea of dupli-

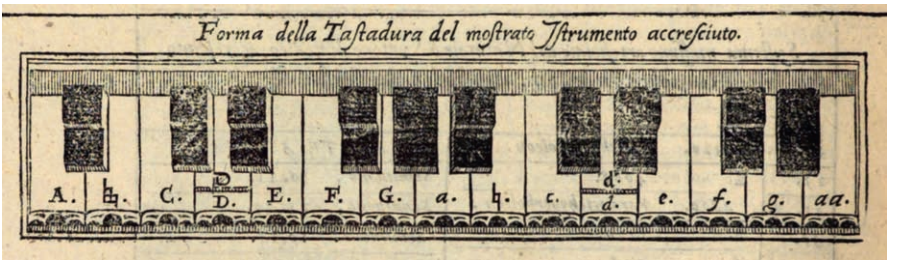
20 See Denzil Wraight, "The 'cimbalo cromatico' and other Italian string keyboard instruments with divided accidentals", in: *Schweizer Jahrbuch für Musikwissenschaft* N.F. 22 (2002), 105–134: 131.

cating the d key and others closely related to it, something I had often thought about since reading Ercole Bottrigari's *Desiderio* (1594) many years ago:[21]



Ill. 6: Sketch for "la vera pluralità di corde" by Ercole Bottrigari, *Il Desiderio* (Venice 1594), 30.

In fact, Zarlino in his *Sopplimenti musicali* (1588) had already proposed a 16-note keyboard six years earlier.[22] Here F# is also doubled (while of course C# and G# are present; see ill. 7).



Ill. 7: Sketch of the keyboard of an 'Jstrumento accresciuto' by Gioseffo Zarlino, *Sopplimenti musicali* (Venice 1588), 156.

While this basic scheme doubles B♭ and E♭ as well as D, it seemed necessary to have D# and A# as well as to duplicate F#. We thought it a good idea to have one triad that would be duplicated in both its minor and major form, so, having started off with two B♭s and two Ds, it seemed logical to double the Gs and the B♮s as well. As an experimental keyboard with a shorter range than his *cromatico*, Willard felt it was just possible to make such a keyboard that could be used in the same harpsichord. Of course, with more notes per octave, a lot of retuning – necessitating pulling up many bass strings in pitch and lowering tre-

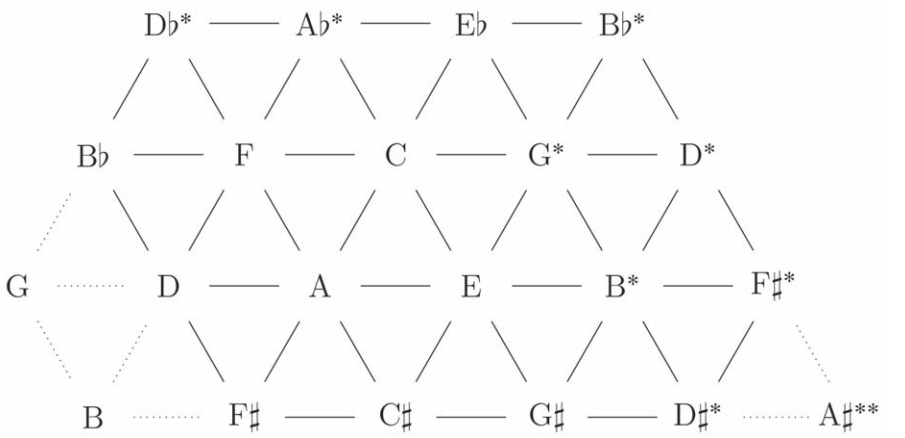
21 Ercole Bottrigari, *Il Desiderio overo De' Concerti di varij Strumenti Musicali*, Venice: Ricciardo Amadino 1594, esp. 28–31 (quote on p. 30).

22 Gioseffo Zarlino, *Sopplimenti Mvsicali*, Venice: Francesco de' Franceschi Senese 1588, 152–157: 156 ("Jstrumento accresciuto").

ble strings. He decided that 21 keys per octave would be the maximum. This meant that, while the black key between A and B could be split into three to provide A# as well as the two B♭s, it would not be possible to make a similar division elsewhere; this meant that when two different E♭s were required, the D# key could simply be retuned (see ill. 8).

Ill. 8: The 21-note experimental keyboard made in 1999 by Willard Martin, Bethlehem, PA.

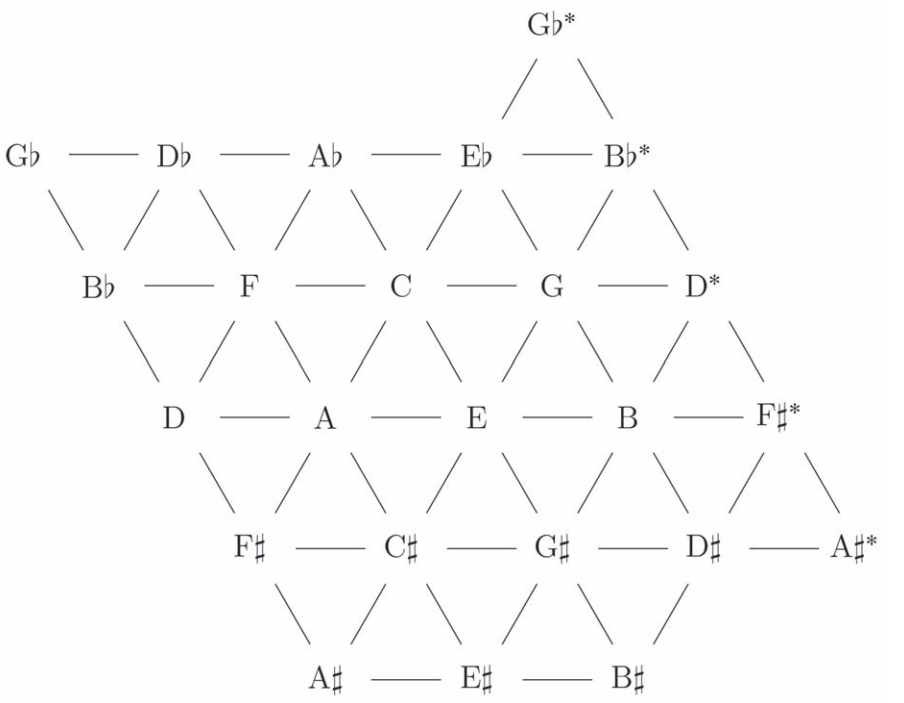
The 21-note per octave keyboard by Willard Martin is tuned to give four series of pure fifths, related to each other by pure minor and major thirds. The notes marked * are played on the rear keys. In the case of D#, A♭ and D♭ these are the extra notes as found on most keyboards that have extra semitones, A#** being a third key placed above and behind the two B♭s; while G*, B*, D*, F#* and B♭* are pitched a syntonic comma higher than G, B, D, F# B♭:



Ill. 9: The tuning scheme of the keyboard illustrated in ill. 8 All the lines joining the fifths and thirds represent pure intervals.

On my next visit to Bethlehem, the keyboard was already functioning and sitting down and trying to play it brought back some of the amazement that one must have had as a child when first trying the notes of a piano. Willard agreed to lend me the instrument for a year and I had it at home in South Tyrol and enjoyed playing around for hours, improvising, discovering dozens of different ways of rendering the opening of Wagner's *Tristan*, but, alas, even after months, not being able to play anything – even in C major – very fast.

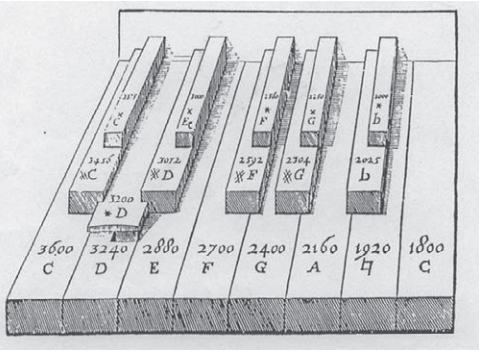
Salinas had a 24-note keyboard tuned to just intonation and, if the description in his *De Musica libri septem* is to be taken literally,[23] while no diatonic key apart from *d* was doubled, not only were all the chromatic keys (including B# and E# as on the *cimbalo cromatico*) present, but A# and G♭ were duplicated – thus the black keys between A and B, and between F and G were each split into four.



Ill. 10: The 'Tonnetz' of Salinas 24-note just-intonation keyboard.

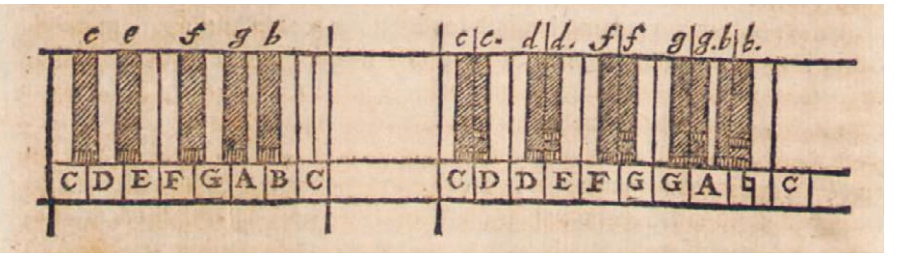
23 Salinas, *De Musica libri septem*, 122.

I was, of course, conversant with the engraving by Albert Ban of a keyboard with 18 notes to the octave proposed by Mersenne, which does not follow Bottrigari's doubling of E♭ but instead has a second F# (see ill. 11).[24]



Ill. 11: Diagram of a 'perfect keyboard' from Joan Albert Ban, *Kort zangh-bericht* (Amsterdam 1643), 28.

This is a more logical starting point since it recognises the fact that *d* is central to the system, being exactly halfway between the flats and the sharps (it is also the central key on an Italian keyboard which has the range C/E–c''') and then gives us one split flat and one split sharp. Descartes modified the Ban/Mersenne design by adding one more extra key, doubling the *g*, thus creating a keyboard which, like the *cromatico*, has nineteen divisions to the octave (see ill. 12).[25]



Ill. 12: Description of a keyboard by René Descartes, *Epistolæ* (Frankfurt/M. 1692), 337–338.

24 Joan Albert Ban, *Kort zangh-bericht*, Amsterdam: Paulus Matthysz 1642 [1643], 20 and 27–28.

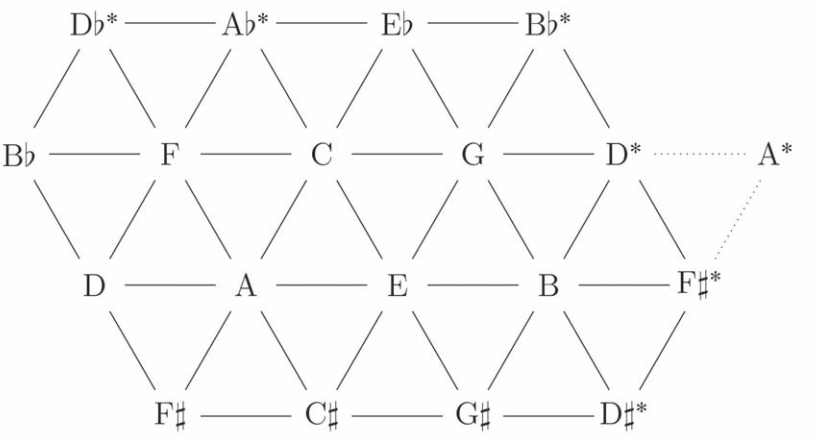
25 René Descartes, *Epistolæ […] Pars Tertia*, Frankfurt/Main: Friderici Knochii 1692, 337–338 ("Epistula XCV. Ad Dominum ****."). It is not clear why Descartes writes "dividenda est in Octodecim" when the diagram clearly shows nine naturals and ten chromatic keys.

Returning to Willard and admitting to the fact that his beautifully made 21-note keyboard had defeated me, he pointed out that obviously a 19-note division of some kind would be more suitable for an alternative keyboard to the 'normal' *cromatico* one, since the instrument that he had built had nineteen strings to the octave. I had observed that the frequent occurrence of the 4/5 dissonance over D, requiring both G and A, is a problem in just tuning since G is in tune with the upper D while A is in tune with the lower D; thus either G or A needs to be duplicated to make it possible for this dissonance to sound well. While I had experienced the joys of having an extra G, it seemed more logical, if we were to have nineteen notes, to have an extra A; this would mean that the D major triad would be duplicated, a useful feature when demonstrating how progressions played or sung in perfect tune involved slight changes in pitch. (An extra G would give a duplicated minor triad but no major one.)

Once Willard had made this new 'Descartes' keyboard, he generously allowed me to play on it for many hours before deciding where the split keys should actually be divided in the final instance; this made a lot of extra work for him. As may be seen from the photograph (see ill. 13), the split keys are not uniform. This reflects the fact that, for instance, the front key which plays E♭ is played together with the back key which plays the upper B♭, while the rear key that plays D♭ is played with the lower B♭ (front key) and similarly G# needs to be played with D#. The upper a key, not being in Descartes' plan, was made quite short.

Ill. 13: Keyboard after Descartes by Willard Martin, Bethlehem, PA (2001).

19-
The ~~21-~~note per octave keyboard by Willard Martin is tuned to give four series of pure fifths, related to each other by pure minor and major thirds. The notes marked * are played on the rear keys. In the case of D#, Ab and Db these are the extra chromatic notes as found on the 19-note chromatic keyboard; while D*, A*, F#* Bb* are pitched a syntonic comma higher than D, A, F#, Bb.[26]



Ill. 14: The 19-note per octave keyboard by Willard Martin is tuned to give four series of pure fifths, related to each other by pure minor and major thirds.

While the initial quest for split keys was marked by the recognition that there are quite clearly two different kinds of semitone – and that for the performance of a large body of music this difference is important – this keyboard, the fruit of being driven even further to pursue a truer sound, has inevitably dragged us back into the more unexplored territory of unequal whole tones. It indeed gives us the satisfaction of being able to play a large number of pure triads (11 major and 11 minor triads, not counting the extra D major triad); but the fact that any melodic progression consisting of two whole-tone steps – whether conjunct or separated by a semitone – will contain two slightly different intervals, major and minor tones, can elicit negative as well as positive reactions in the listener. Above all it is the combination of harmonic and melodic progressions that can be problematic, or more particularly, the combination of a held melodic note over a changing harmony. If, in C major, a d' played as a sixth above f continues then as a fifth above g, it has to rise in pitch if it is to be in tune. Similarly,

26 When playing music for which Db and D# are not required, these keys can be retuned: it is useful to have a second C# in tune with the higher A and a second Eb for use as a suspension with F and (lower) Bb, resolving onto the lower D.

when a chord of B♭ is followed by a chord of G minor, both the B♭ and the D will have to change pitch. (The 21-note keyboard which offers an additional lower G could avoid the latter problem, but then, as the music progresses, a similar problem is likely to occur on a different degree of the scale.) In homophonic music there are cases where the purity of the accompanying chord can beguile the listener into accepting the readjustment of the pitch of a particular note; a momentary sense of disorientation is, as it were, banished by the convincing feeling of being at home.

There is a very small amount of music that can be played satisfactorily on this instrument using this keyboard. Certain pieces that remain largely restricted to one or two triads – such as those from William Byrd's *The Battel* – work very well. Occasionally pieces centred on F major or a minor, and more rarely C major, can be found that do not stray far from the tonic. It is interesting to note that a melody like *Will you walk the woodes so wilde?* in the piece by Byrd where the strains alternate using tonics a tone apart, F and G, which on this keyboard are a major tone apart, sounds better transposed up a tone so that the difference in pitches is only a minor tone. This could be caused by simply hearing two different pitches for the sixth of the lower tonic and the fifth of the upper one (*d* in the first instance), a difference which is eliminated in the transposed version. It begs the question whether the size of the whole-tone in such cases was of importance.

Such questions are relevant to music of any period. The opening chords of Vaughan Williams' *Fantasia on a theme by Thomas Tallis* – they have to be transposed up a tone on this keyboard since it has no G♭ – sound particularly striking probably as a result of the two different sized major tones in the bass scale, the progression from the first to the second note being a major tone, from the third to the fourth a minor tone, although the harmonic progression is identical in each case, from root position to a 6/3 chord (all chords are major). Much can be learned from playing even short passages from compositions in this way. While the restrictions of the keyboard make it impossible to play more than a short section, in a case like this such nuances are worth considering and could well be adopted by string players. Furthermore, the keyboard increases our awareness of possible different pitches for one and the same note and clearly, to a lesser extent in normal tempered performance, such notes can and should be adjusted by singers and string players to accommodate harmonic changes.

The 'Descartes'-keyboard is therefore primarily for experimental use in exploring and understanding the quality of intervals. Performing on the keyboard itself, it is interesting to improvise. In this case it is possible not only to avoid problems that may disorientate the listener, but also to use the duplicate notes

for special effect. Raising D when passing from a B♭ major chord to G major makes for an exciting progression which could be applied to vocal or string performance in certain contexts. As already mentioned in connection with 1/3 comma meantone, our ears are not used to hearing pure minor thirds; there are thirteen such intervals available on this instrument. In four cases the keyboard offers an interval quite close (almost 7 cents wide) to the pure seventh harmonic (7/4), d♭–b, f–d#', a♭–f#*' and b♭–g#'. This added to the pure triad provides a startlingly beautiful consonance and helps to explain why the so-called pure minor seventh (16/9) otherwise available is not very convincing when added to a pure triad; when added to a tempered triad on the other hand, it is acceptably consonant. The acute minor seventh (consisting of a pure fifth and a pure minor third) is however even more uncomfortable as it fails to have the downward pull of the lower version. The addition of other dissonances to a pure major triad can create chords which are at least as consonant as the ordinary minor or major seventh. For instance, in the case of an added sixth, the dissonance is a pure major sixth from the tonic and a pure fourth from the third of the triad.

It is thus possible to hear, in a new light, a range of harmonies, not necessarily connected with early music, that we are accustomed to hearing in tempered tunings. While the instrument's limitations remind us why we have to choose a less complex keyboard and live with compromise, it can reveal to our ears the harmonies that are often implied even if, for practical reasons, they can rarely be executed in their ideal form. For performers not restricted by fixed pitches, in particular singers and string players, it can be an aid to understanding the harmonic and melodic implications of a piece of music and indicate which notes could or should be pitched a little higher or a little lower.

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