

The Monochord according to Marin Mersenne: Bits, Atoms, and some Surprises

Carlos Calderón Urreiztieta
Universitat Pompeu Fabra

Based on the text and figure from Proposition XII of the “Book of the Instruments” in Harmonie Universelle by Marin Mersenne, a digital-virtual monochord (multimedia and interactive) and a real-material one (wood and gut strings) have been created to investigate and verify, both numerically and acoustically, the musical science of this natural philosopher. Mersenne’s monochord is presented here as a piece of evidence in the continuity of the history of science, that is, the conclusion of some metaphysical traditions, and as prologue of what we call an-aestheticized modern science. These reconstructions help to read some chapters of the Harmonie Universelle in a multimedia way, convinced as we are that musical treatises—especially from the 17th century—have to be “heard” in order to reach a full understanding of their propositions. A fundamental link for this essay is: http://www.calderon-online.com/mersenne/monochord_mersenne.htm

Preliminary thoughts

Among the huge catalogue of instruments shown in Mersenne’s *Harmonie Universelle* the monochord stands out due to its two fundamental tasks: to provide the exact intonation in the calibration of musical instruments and to demonstrate, as Mersenne says, “all the science of Music” (Mersenne [1636] 1965, III, I, p. 16). The former is, at least in principle, a practical task for singers and performers; the latter, a theoretical one for natural philosophers, both of them for the true musician. The discussion about what a “true musician” is was summed up early on, in the 6th century, by Boethius (see Cap. XXXIV of First Book of *De Institutione Musicae*) in three genres: the performers who take up only instruments and the poets who deal only with verses. For Boethius the first have no musical understanding and act like slaves, the second have only natural instinct for their



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compositions, but the third genre, the musicians—the true musicians—are those who have the ability to judge musical rhythms, *cantilenas*, and compositions in general according to theory and calculation. Thus, Zarlino in the 16th century formulated the discussion in almost the same way, setting up the difference between *Cantore* and *Musico*, but clarifying that the perfect musician—*Musico perfetto*—is that one who gives to his expert practice the faculty to judge with reason, turning his science to perfection (See Prima Parte, Cap. 11 in *Institutione Harmoniche*). This two-sided condition is inherent in practically the whole discussion around music as an art-cum-science and it is well illustrated, as we will see, in Mersenne's approach to the monochord. [Fig. 1]

As is well known, the monochord did not emerge like other new instruments into the early 17th century scene—as did the telescope, microscope, or vacuum pump—but rather as a simple instrument frequently used from antiquity up to the 17th century. It consisted of a tense and vibrant string that could be shortened by means of a movable bridge so as to define a certain proportional relation (geometric, arithmetical, and acoustically perceptible) between its longer and shorter parts: the harmonic *ratios*. Its simplicity and high precision were always praised by philosophers and musicians and, in the case of Mersenne, it could serve as a testimony of what Crombie calls a “new science”: “*The new science of music illustrates in this age of transition {between the middle of the 16th century and the middle of the 17th} how with new scientific experience a fundamental task came to be seen as that of tailoring ancient philosophical ambitions to the possible, the testable and the soluble*” (Crombie 1994, Vol. 3: 786). We only have to clarify that despite the emergence of a new science of music, the monochord was not a “new scientific experience” and, moreover, already formed part of those “ancient philosophical ambitions” and came from the same origins. Conceived by Pythagoras—according to the story transmitted by Nicomachus of Gerasa, c. AD 100—it was very frequently used during the Ancient, Medieval, and Renaissance periods.¹ In this sense, the heuristic capacity of the monochord spans from the sensible and audible confirmation of the consonance—from Euclid to Zarlino—to the structural and meta-

1. As Jan Herlinger has quoted: “Ancient Greek music theory developed canonic [theory and practice of monochord] to a sophisticated degree . . . The *De Institutione musica* (early sixth century) of Boethius transmitted a number of . . . tunings to the Latin Middle Ages . . . Western musicians and scholars devoted a great deal of attention to *De Institutione musica* from the ninth century at the latest, and from about the year 1000 divisions of the monochord proliferated in Latin music theory. The extant corpus of texts dealing with canonic written in the West between c. 1000 and 1500 runs about 150 items; and the authors of any number of other Medieval treatises presupposed a knowledge of canonic on the part of their readers” (Herlinger 2002).

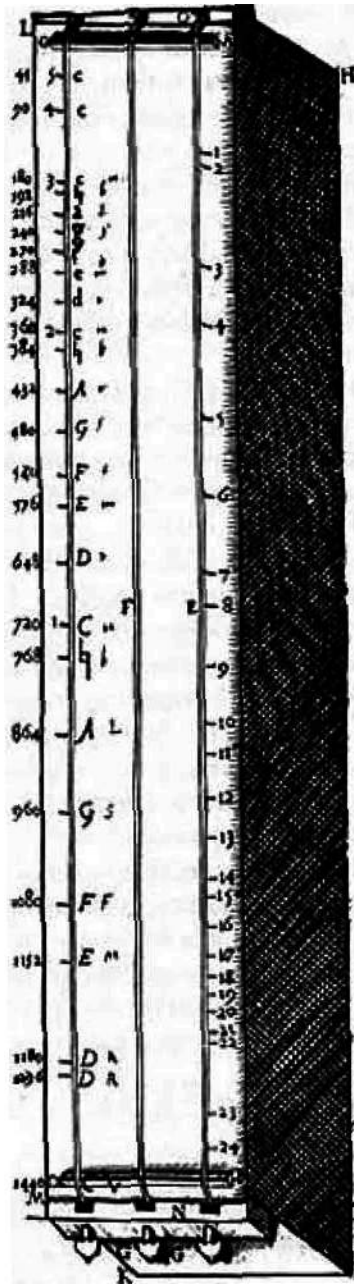


Figure 1.

phorical power shown as much in Ptolemy and Kepler as in Fludd and Kircher.

Nevertheless, it is clear that experimenting with monochords did not result in new “soluble and testable” experiences and it is possible to say that the experiments that Benedetti, Vincenzo Galilei, Zarlino, Kepler, Galileo, and Mersenne carried out in the 16th and 17th centuries to give birth to a “new musical science” could be seen as an expansion of the possibilities of this pioneering scientific instrument.² In a way, the monochord is a piece of evidence in continuity from natural philosophy to modern science; we can say this because music and monochords—whether they are seen as theory, practice or pedagogy—have always been related to two important aspects in the development of natural philosophy as a social discipline:

- i. *Institutionalism*. Musicians—both theoreticians and practitioners—found a clear place in society, especially through monasteries and religious services—singing and teaching—and later in court—with celebrations and performances. Music, and its science and practice, has always been present.
- ii. *Moral responsibility*. Music has always kept a meta-goal in humanity: from the good well trained Greek citizen to the well prepared soul ready to receive God’s musical words, rejecting—as Lutero said—Satan from our spirit. Music made you a good person.

In these two aspects—institutionalism and moral responsibility—music science was never isolated from society, its social legitimation being reached because the monochord was the only material object which served as a physico-mathematical grounding of this theoretical and practical knowledge. Thus, music and science of music never stopped and there is no break in continuity in this discipline at the moment when modern science arrives. Notice, moreover, that the monochord is the only material and experimental object that justifies Mersenne’s impressive title: *Harmonie Universelle*. In this work the explicative power that harmony can offer is finally justified by that simple and vibrant string. As Peter Dear says, “. . . the use of the monochord remained *the sole technique* [my italics] by which the intersection of ratios and musical intervals could be realized; without it, the ratios would have been meaningless” (Dear 1988, p. 142).

We have to clarify that the intersection of these mathematical ratios and musical intervals remains, above all, in the aesthetic experience. It is a

2. For an experimental approach to music in the hands of 17th-century natural philosophers see *Quantifying Music* (Cohen 1984) and an essay by Stillman Drake “Renaissance Music and Experimental Science” (Drake [1970] 1999, p. 201).

sort of acoustical mathematics, but a beautiful one. The refined ear and the pleasant sounds are the final judges and the monochord as scientific instrument is the only place where this scientific-aesthetical practice could be experienced in both rational and empirical ways.

In the first part of this essay we analyze Mersenne's Proposition XII of "The Books on Instruments." The natural philosopher shows the two-sided condition—practical and theoretical—of this instrument. In order to reach a wider and deeper understanding of Mersenne's propositions we make two reconstructions: a virtual-digital one that could be "played" in the computer according to Mersenne's instructions and a material one that would allow us to calibrate the real acoustic dimension. In the second part of this essay we explain both reconstructions—material and digital—and invite the reader to navigate a web link where the virtual monochord is located. This virtual-digital reconstruction helps to read some chapters of the *Harmonie Universelle* in a multimedia way, convinced as we are that musical treatises—especially from 17th century—have to be "heard" in order to reach a full understanding of its propositions.³ Finally, we show how, "in the span of only pages," Mersenne split this double condition to produce, what we call, the *an-aestheticized* scientific judgment.

Proposition XII

Mersenne stressed the relevance of the monochord in Proposition XII by claiming that the theoretical results achieved by the preceding propositions were enough to provide the essence of the instrument:

If one understands the preceding propositions, there is no need to explain the monochord here, inasmuch as I have discussed it so amply and exactly, that nothing more can be desired (it seems to me), unless it be that the performers think the discourse to be too speculative. The method of constructing it is seen at the end of the Fourth Proposition, where I have explained the harmonic rule of Ptolemy; nevertheless I am placing here a particular figure so as to come to terms with the practice and usage, so that there be no instrument maker or musician who does not comprehend it as well as I do and cannot reestablish music by its means, even though it [music] be lost and effaced from the memory of men.⁴ (Mersenne 1957, p. 46)

3. Another example of multimedia and interactive projects in History of Science is *Harmonice Mundi, Book V: multimedia and interactive version 1.0*. It can be played on-line at this link <http://www.calderon-online.com/kepler/harmonicemundi.htm> (Flash application, 29.2 mb).

4. "Si l'on entend les Propositions precedents, il n'est pas besoin d'expliquer icy le

The previous Propositions have shown a compendium of subdividing the string in a strictly mathematical-geometric mold and there is nothing explicitly material or acoustical in them. Mersenne aligns himself with the intellectual inheritance that had, from Boethius to Zarlino, paid attention to the monochord visualized as a line, with all its abstract and geometric aspects. Nevertheless, Mersenne insists in offering a figure and a material object to guarantee the eternity of his science.⁵

Proposition XII shows a small but exquisite sample of scientific musical knowledge in early 17th century and particularly of Mersenne's approach. Notice, on one hand, that his confidence in abstract and mathematical reasoning makes Mersenne declare the figure of the monochord unnecessary. On the other hand, notice Mersenne's awareness of the practical and constructive aspects of musical instruments that induces him to assume that all the musical science is contained in this object. Notice the tension between the two positions. Both approaches share musical truths and nevertheless, neither seems to need the other. Theory and practice unenthusiastically face each other. And the field of battle—or of concordance—is the monochord.

For those who enjoy recreating instruments or experiments from the history of science and delight in denying or refuting the results that the scientist arrived at, this experience will defraud them. In 17th century the monochord had more than twenty centuries confirming its truths: the string sounds in a consonant way according to the Pythagorean proportions 1:2, 2:3, 3:4. Subsequently Ptolemy and, much later, Zarlino, Kepler, and Mersenne—with reasons ranging from numerology, geometry and acoustic experience—granted the proportions 4:5, 5:6, 3:8 and 5:8 as

Monochorde, d'autant que i'en ay discoursu si amplement & si exactement, que l'on n'y peut (ce me semble) rien desirer, si ce n'est que les Practiciens croient que les discours en foient trop speculatifs. L'on void aussi la maniere de le construire sur la fin de la quatriesme Proposition, ou i'ay expliqué la regle harmonique de Ptolomée; neantmoins i'en mets encore icy vne figure particulaire, afin de m'accommoder tellement à la Practique & à l'vsage, qu'il n'y ait nul Facteur d'instruments ou Musicien, qui ne le comprenne aussi bien que moy, & qui ne puisse reestabli la Musique par son moyen, encore qu'elle fust toute perduë & effacée de la memoire des hommes" (Mersenne [1636] 1965, Vol III, Liure I, p. 32).

5. Regarding the power of images displayed in his Book, Mersenne says: "It is certain that the shape of a musical instrument will aid greatly the imagination of the readers, and that they will understand more in a quarter of an hour than they would in a day without the help of these figures, . . ." (Mersenne 1957, p. 15). ". . . il est certain que la figure des instruments de Musique soulagera grandement l'imagination des Lecteurs, & qu'ils en comprendront plus dans vn quart d'heure, qu'ils ne seroient dans un iour sans l'ayde desdites figures, . . ." (Mersenne [1636] 1965, Vol III, Liure I, Preface au Lecteur, p. s/n).

consonances.⁶ For the rebuilder, there will be no surprises. If there are, they are somewhere else.

The virtual reconstruction

First of all, the figure shown in Proposition XII was digitized and with a digital ruler⁷ we verified the precision of its marks and the accuracy of the measuring ruler that Mersenne set at the right margin of the instrument. If we consider that many of the musical instruments in *Harmonie Universelle* were drawn or illustrated in a tradition of copying and transmission from early sources as some kind of cultural or encyclopedical records⁸—some of them richly decorated, fanciful and totally inaccurate—it is particularly surprising that this new image of Mersenne's monochord—not built over this tradition and completely aside from any kind of symbolism—was badly drawn. We were surprised by its inaccuracy. [Fig. 2] Not only is the central octave mark not in the midpoint but also differs in both outer strings. The rest of the marks are also slightly misplaced. But while the *comma* between the two D's is quite exact, the octave C and the number 8 are incorrect. In spite of being considered so essential (see Note 5), the figure was simply inaccurate and neither the printer nor Mersenne himself noticed it, or if they did, Mersenne took no action to correct it, or wrote anything about it in his handwritten annotation in his own edition.⁹

Therefore, it was necessary to rectify the image, rearrange the measuring ruler and “move”—digitally speaking—the marks to the exact position according to the numerical proportions that Mersenne indicated in the text. If we faithfully reconstructed the monochord by following Mersenne's figure, our ears would have immediately noticed the errors and “all the science of music” would be a fake. It was not necessary to experience it.

Once the image was rectified, we took on the virtual reconstruction. Using Macromedia's Director software we reconstructed not only the

6. For a revision of the history of consonance and harmonic *ratios* see Barbour (1951).

7. Adobe Photoshop.

8. See Barker, N (2007).

9. We could read in the handwritten annotation: “Les recontres de ces 2 chordes peuvent, peut estre, servir pour trouver pouquoy une mesme chorde fait son proportion et puis la douzieme, car estant divisé en 4 la totale fait avec sa moitié l'octave et avec la quarte la 15eme et 3 parts sont contrer une part la douzieme.” Special thanks to Claudio Buccolini for the analysis and reading in the Seminar “Mersenne and the mixed mathematics.” Universitat Pompeu Fabra, Barcelona. Mayo 2006. Other reconstructions of Mersenne's instruments show us how to deal with this imperfection or missed information. See Robinson (1973).

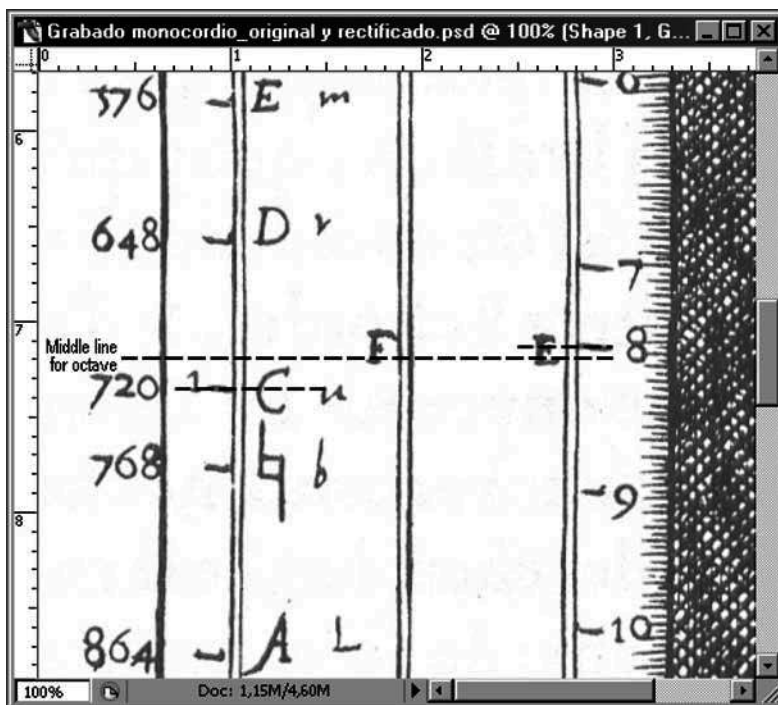


Figure 2.

apparatus to be manipulated and listened to in the way Mersenne indicated, but also the process for its construction. This way, Proposition XII is read interactively while the monochord is being constructed step by step on the screen. We kindly request the reader to play the software on-line at this link: http://www.calderon-online.com/mersenne/monochord_mersenne.htm

Mersenne explains the monochord and his technique following these stages:

- i. Let the monochord be of whatever length or width as long as you use the figure and his marks as master plan.
- ii. Set three strings of the same length determined by two fixed bridges and attach them at the top to an iron nail and below to a peg. Use strings preferably from a lute or a spinet.
- iii. Use a small bridge under the outer strings and move it along to shorten the string and produce whatever consonance or dissonance

or interval is wished. The middle string has no division and always represents the entire tone sounding open against all the divisions of the two outer strings.

- iv. Use the pegs to bind, loosen and put the three strings in unison.
- v. According to the marks, play the outer strings against the middle one to produce the intervals in this order: 9:10 minor tone, 8:9 major tone, 5:4 major third, 3:4 fourth, 2:3 fifth, 3:5 major sixth, 8:15 major seventh and 1:2 the octave. Play the rest of the intervals that are replicas of the precedent ones.
- vi. Pay attention to interval 80:81 *comma*, produced between the major tone and the minor tone. It is marked only in the first octave.

Users may notice that tension is a variable that Mersenne did not contemplate playing with. In his previous Proposition IV he has renounced the use of weights suspended on strings to calibrate pitches because “One would not know the ratio of the weights which are necessary to place the strings at all sorts of pitches, and then the strings themselves often raise or lower their pitch, although they be held with the same weights, and were they perfect equal, they would not keep the ratios of the pitches . . .”¹⁰ (Mersenne 1957, p. 28). Mersenne is aware of the complex variables that affect pitch on a vibrant string—humidity, temperature, dimensions and quality, etc.—and therefore the string in his monochord continues being assimilated to a line which, after all, cannot be tensed or tuned in the abstract and geometric universe of 17th-century musical science. The tension and its association with pitch and frequency belonged to the acoustics era that Mersenne himself was contributing to create.¹¹

Leaving aside the “tension” variable, Mersenne did incorporate the tone color—timbre—as a variable to play with. He suggests using gut strings (as in a lute) or metal strings (as in a spinet) and encourages us to compare the tone color as is shown in the multimedia. In this case, materials cannot be reduced to the abstract and geometric universe, but Mersenne is a devotee of 17th music and its well known colored range of sonorities and instruments.

Once the three strings are tuned in unison and the type of string selected, the user can fit the acoustical and mathematical values moving the bridge directly or entering numerical values. [Fig. 3] It is still possible to

10. “on ne sçauroit treuver la raison des poids qui sont necessaires pour mettre les chordes à toutes sortes de sons: & puis les mesmes chordes haussent souuent ou baissent leurs sons, bien qu’elles soient tédües avec mesmes poids; & quád elles seroient parfaitement égales, elles ne garderoient pas la raison des sons . . . :” (Mersenne [1636] 1965, Vol III, Liure I, p. 15).

11. For a history of frequency in music see: *Early Vibration Theory: Physics and Music in the Seventeen Century* (Dostrovsky 1975).

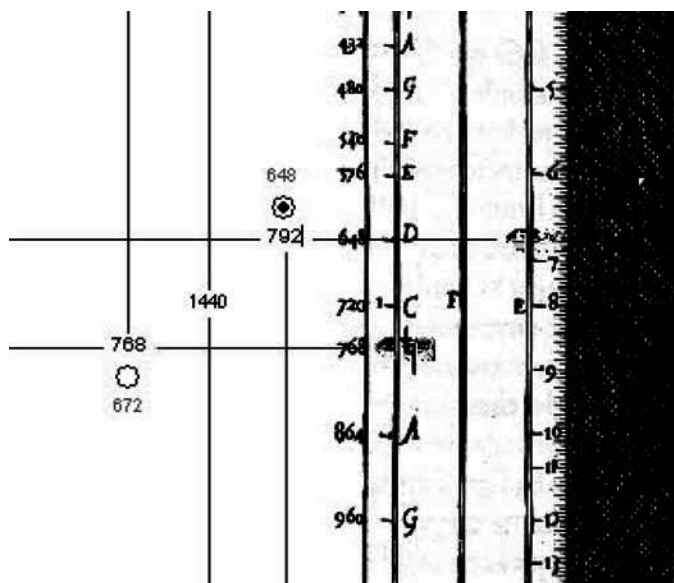


Figure 3.

zoom in for greater precision. Finally, we have placed a guided visual summary, to locate all the proportions that Mersenne has investigated throughout his Propositions V to VIII: from proportion 1:2 to proportion 1:161. [Fig.4]

Catch the minimal acoustical differences and do what Mersenne did reading him in a full multimedia way. If you like placing numbers freely according to some criterion and verifying consonant or dissonant characters, do not expect any great surprises. Just do what natural philosophers had been doing since ancient times and throughout musical science history: to find the exact proportions for consonance sounds and to be moved by verifying this ancient law of science which establishes correspondence between a numerical value and physical—and aesthetic—reality. Now, a virtual digital one.

The material reconstruction

Mersenne's writing is sufficiently precise to enable one to build a monochord similar to the one in his illustration. [See Fig. 1] Some details, however, including size, strings, woods and ornamental features were left *ad libitum*. For the material reconstruction, we contacted the luthier, Ramon

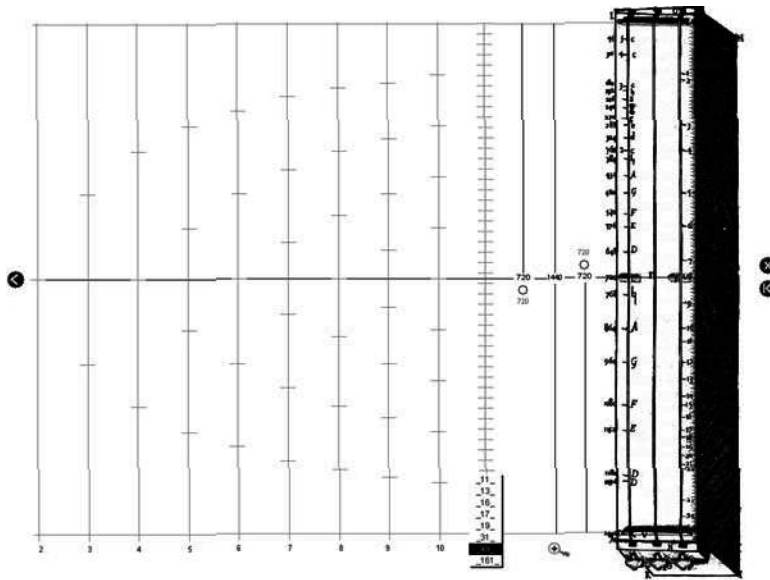


Figure 4.

Elias Gavernet¹² who accepted the invitation out of his love for antique instruments. In the same website the reader may watch on-line some recorded stages in video of this reconstruction, which follows Mersenne's instructions as accurately as possible.

In summary the material characteristics for this "standard" Mersenne monochord are as follows: [Fig. 5]

Size: Mersenne left dimensions up to the reader and the string in his figure was "only seven and a quarter inches,"¹³ "which can be doubled and multiplied as many times as one wishes. . . ."¹⁴ (Mersenne 1957, p. 47). In Proposition V, he is more explicit. The monochord could be as much as 3, 6, 12 or 24 feet in length. He recognizes that these huge monochords

12. Ramon Elias Gavernet. Luthier. Qualified as a Technician and Specialist in Liutaio, 2003, from the I.P.I.A.L.L. Istituto Professionale Internazionale per l'Artigianato Liutario e del Legno "Antonio Stradivari"—Cremona, Italia. Gavernet has his workshop in Altet (120 km from Barcelona, Spain). For contact: ramoneg@telefonica.net.

13. The equivalence is 2.735 cm for Mersenne's inch and 32.8 cm for a foot. (Lenoble 1943, Section IV p. LXIII).

14. ". . . seulement donné 7 pouces & 1/4 de longueur de celle cy, que l'on peut redoubler & multiplier tant de fois que l'on voudra: . . ." (Mersenne [1636] 1965. Vol III, Liure I, p. 32).



Figure 5.

could be used in principle for all kinds of experiences and to extract all types of conclusions about the nature of sound. However, “if one wishes solely to note the pitch of the sounds and all their differences, it is enough to have a monochord of one, two or three feet.”¹⁵ (Mersenne 1957, p. 30) According to Mersenne’s value of 1440 units in the right margin of the instrument,¹⁶ we decided to build a 72 cm monochord. This number is a simple divisor of 1440 and allows the marks to be transferred easily. Besides, 72 cm is equivalent to 2.20 of Mersenne’s feet and is also an average dimension for lutes, the most frequently played stringed instrument at that time.

Wooden box: Mersenne indicates in Proposition V that even though any

15. “car si l’ont veut seulement remarquer le graue & l’aigu des sons, & toutes leurs differences, il suffit d’auoir vn Monochord d’vn, de deux, ou de trois pieds: . . .” (Mersenne [1636] 1965, Vol III, Book I, p. 17). Mersenne indicated that his figure corresponds to a Diatonic monochord, but he assured, having played a 4 feet monochord and due to its dimension, it is possible to experiment with “the three genres [Diatonic, Chromatic and Enharmonic] perfectly” (Mersenne [1636] 1965, Vol III, Book I, p. 34).

16. In Proposition XII Mersenne uses the number 1440 to ease the building and calculations of mathematical proportions providing a sequence of entire numbers that matches the harmonic proportions. In Proposition IX, more abstract and speculative, he uses a larger number: 3600.

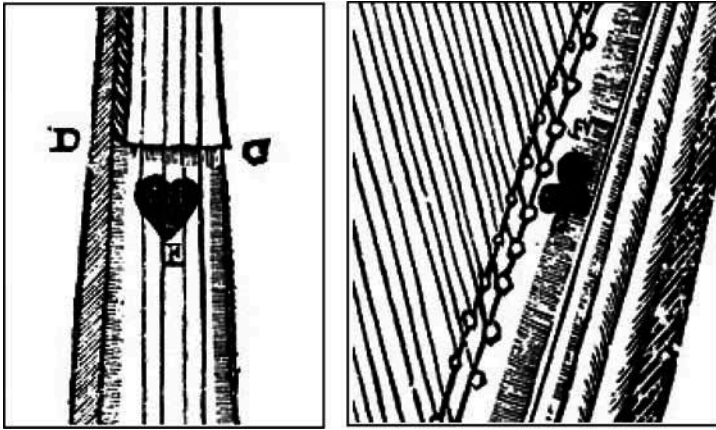


Figure 6.

wood could be used, the preference was for “. . . the fir, cedar and other resonant woods, of which are made lutes, viols and the other instruments”¹⁷ (Mersenne 1957, p. 30). Following these indications, fir was selected for the sides and top, and cedar for the bottom. The pieces were glued using parchment strips as Mersenne briefly describes for the construction of Lutes and following the contemporary process of 17th century procedures.¹⁸

In order to obtain the best resonance, Mersenne suggests to “. . . make some opening on the table or at the sides of the monochord, similar to the rose of the lutes, or the sound-holes of the harps or the viols”¹⁹ (Mersenne 1957, p. 48). In line with this, the luthier made a design of his own resembling holes of other instruments shown in Mersenne’s book. [Fig. 6–7]

Strings: Mersenne indicates that any kind of string can be used, but in his Proposition V he recommends that “those of brass or steel are better than those of gut, in that they are not subject to so many alterations and changes. . . .”²⁰ (Mersenne 1957, p. 30). But, he later adds, that it is of no

17. “. . . le sapin, le cedre, & les autres bois resonants, don’t l’on fait les Luths, les Violes, & les autres instruments”. (Mersenne [1636] 1965, Vol III, Liure I, p. 17).

18. See Proposition II of Second Book of the Book of the Instruments. (Mersenne [1636] 1965, Vol III, Liure II, p. 49).

19. “. . . l’on peut faire quelque ouerture sur la table, ou aux costez du Monochorde, semblable à la rose des Luths, ou à l’ouye des Harpes ou des Violes, . . .” (Mersenne [1636] 1965, Vol III, Liure I, p. 34).

20. “. . . mais celles de leton ou d’acier sont meilleures que celles de boyau, d’autant



Figure 7.

importance “. . . whether one makes them of the intestines of sheep or of brass” (Mersenne 1957, p. 48).

For our reconstruction, we decided to use gut strings such as would fit into a lute of similar dimensions. The tensions it would be submitted were so that it produced an average sound of a G at 196, 00 Hz (G3, G key in the third octave of the piano). Following Mersenne’s figure, these strings were fixed to an iron nail (typical of spinets) and pegs. The bridges and pegs were typically made of ebony. [Fig. 8]

Support: As an additional element, the luthier elaborated a pair of legs that serve as support for the instrument to allow the maximum resonance. These legs were made in the “French” style, with its curvature and inclined cuts.

qu’elles ne sont pas suiettes à tant d’alterations & de changement, . . .” (Mersenne [1636] 1965, Vol III, Liure I, p. 17).

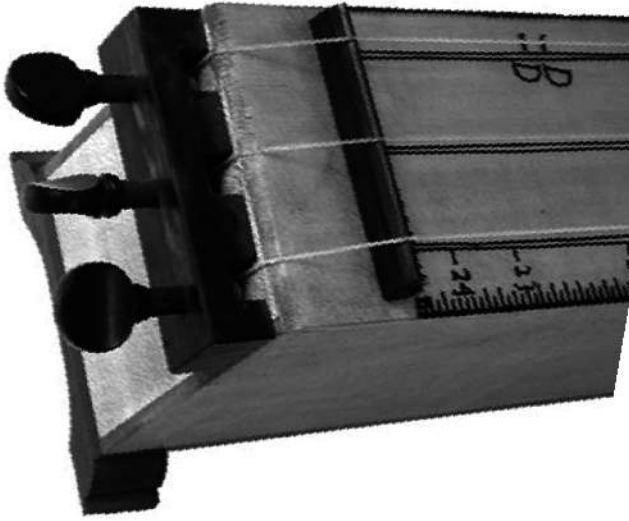


Figure 8.

Finish: Although Mersenne did not mention it, transparent varnish with a minimum touch of color was applied.

Once the instrument was built, the figure of the numerical rule, with the rectifications mentioned above, was enlarged to 72 cm and printed in a transparent sheet in order to place it easily on the top of the monochord. Without affecting the loudness of the instrument—and its naked materiality—this transparent sheet serves as a guide and can be superimposed and exchanged with others to allow comparisons of several subdivisions of the string. [Fig. 9]

Playing the monochord and hearing the infinite

Once the three strings have been tuned to unison, and the transparent sheet put in place with its marks, the performing of the monochord brought not surprise, but delight. The octave is heard as the perfect consonance, and also fifths and fourths. The thirds and sixths show their consonant sound to our well-trained and contemporary ears. The differences between the minor and major tones and the comma are perfectly audible and recognizable. The high pitches are less resonant than low ones but discernible. In summary, Mersenne's monochord works. If we remove the trans-

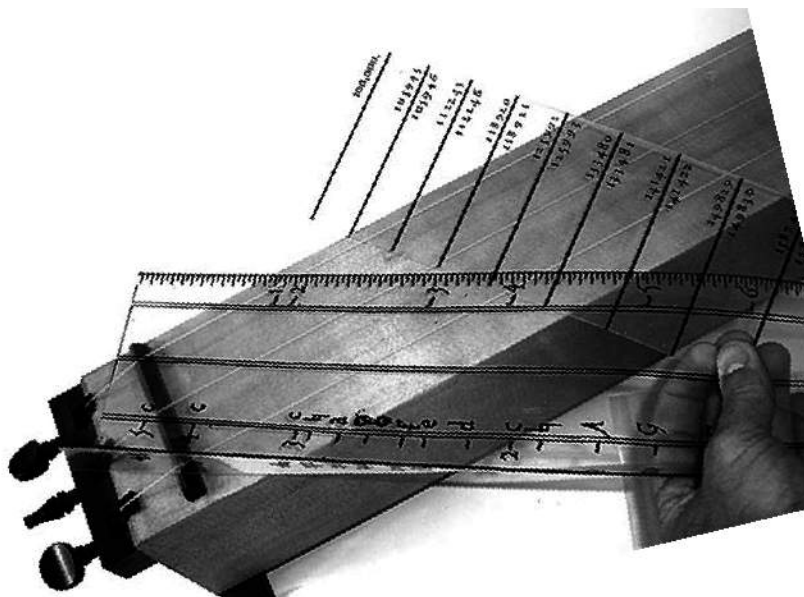


Figure 9.

parent sheet, it would be easy to reconstruct the consonances and harmonic *ratios* through the fact of their own acoustical nature. There have been no surprises, only what we could call hearing the “infinite.” This means that the bridge’s displacement is so easy that once the string is plucked, if we move the bridge, the infinite succession of sounds will be heard perfectly when shortening or enlarging the string’s vibrant length.²¹ Mersenne did not say anything about this in monochords, but had already expressed the existence of this kind of “infinite” when talking about music of viols and violins. “For as there is an infinity of sounds between the low and the high there is, in a parallel fashion, an infinity of colors between black and white”²² (Mersenne 1957, p. 27). Later, he adds

... the violin ... contains all imaginable intervals which are in potency on its neck, in such a way similar to the primal matter, capa-

21. In practical music this effect is called *portamento* and consists of a smooth glide from note to note in a continuous way. In polyphonic music from 16th to 17th century it was used as an embellishment effect in human voice and non-fretted instruments like violin and viols.

22. “. . . car comme il y a vne infinité de sons moyens entre le graue & l’aigu, il ya pareillement vne infinité de coloueurs entre le blanc & le noir” (Mersenne [1636] 1965, Vol III, Liure I, p. 15).

ble of all forms and figures, having no point on the violin's fingerboard which cannot produce a particular tone: thus, it is concluded that it [i.e. the fingerboard] contains an infinity of different tones, similar to the string or the line that contains an infinity of points, therefore it could be denominated *Harmonie Universelle*.²³

Notice how Mersenne has handled this concept of infinity by associating it to sound, color and geometry. It is clear that before 17th century the string was not considered as a continuum; we can see this in 15th century Ramos de Pareja's clear statement: "In the truly perfect monochord there are many places to avoid in singing . . ." ²⁴ Later, in 16th century Zarlino expressed it saying that even though in the monochord ". . . we find the true and natural forms of consonances . . . all the intervals which are found in mentioned instruments [Organs, Harpsichords] are tempered by Musicians in a way that are out of its form and true proportions . . . and this temperament . . . not known by another being rationalized . . . is introduced by chance or not studiously."²⁵ As we can see, before Mersenne, the string was hierarchically segmented and not investigated at all. For Ramos there are forbidden places and for Zarlino there are non-rationalized ones. Thus, we can conclude that for Mersenne, the string has been reconsidered not as a hierarchical segment but a continuum with all its infinity and as we will see immediately there are neither forbidden nor rationalized places for the bridge and therefore none for the tones either.

The preceding condition was required for his subsequent Proposition XIV which talks about "another monochord"—"more useful and easier"—in this case, set in equal temperament.²⁶ The division for this

23. "... le violon . . . contient toutes les interualles imaginables, qui son puissance sur son manche, lequel est semblable à la premiere matiere capable de toutes formes & figures, n'y ayant nul point sur la touche d Violon qui ne fasse vn son particulier: d'où il faut conclure qu'elle [i.e. la touche] contient vne infinité de sons differents, comme la chorde, ou la ligne contient vne infinité de points, & consequemment qu'elle peut estre appellé *Harmonie vniverselle*" (Mersenne [1636] 1965, Vol III, Liure IV, pp. 180–1).

24. "In monochordo vero perfecto multa loca sunt, in quibus transitus in cantu evitandus est" (Ramos 1482 [1990], p. 124).

25. "Et se bene nel mostrato Monochordo si ritrouano le forme vere, et naturali di tutte quelle consonanze . . . tutti quelli interualli, che si ritrouano in detti istrumenti, . . . sono temperati da i Musici, nello accordare detti istrumenti, in tal maniera; che ritrouandosi fuori delle loro forme, o proportioni vere . . . et tale temperamento . . . non so, che da alcun' altro sia stato ragionato . . . sia stata introdutta a caso, et non studiosamente" (Zarlino 1558 [1966], p. 145).

26. There were not exact mathematical and numeric methods for creating this division except approximations and the geometrical and wooden instrument called *Mesolabium* (See Zarlino 1558, *Sopplimenti musical*, Lib. IV, cap. 30, p. 209). Mersenne won't use the *Mesolabium* and calculates irrationals numerical proportional means warning us about "the

Monochorde ou Diapason des touches

I	II	III	IV	V
a	100,000.	c.	100,000.	n
xg	105946	x	105945	m
G	112246	b	112245	l
xf	118921	A	118920	k
F	125993	xg	125992	i
E	133481	G	133480	h
xd	141422	xf	141421	g
D	149830	F	149829	f
xc	158741	E	158740	e
C	168179	xd	168178	d
x	178172	D	178171	c
b	188771	xc	188770	b
A	200,000.	C	200,000.	

Figure 10.

monochord consists of eleven irrational proportional geometric means included between the numbers 200,000 and 100,000. [Fig. 10] These means are presented according to numbers calculated by Jean Beaugrand²⁷ and shown in their contemporary notations. [Fig. 11]

Surprisingly or not, Mersenne displays no specific figure for this monochord—only the numerical table in Fig. 10. Nevertheless, we constructed a new transparent sheet—the “irrational” sheet—as precisely as possible to use on the previous monochord. [Fig. 9] When executing this equal-tempered monochord, we can agree with Mersenne that its division “does not offend the ear and there is no necessity to speak more of it.”²⁸ Mersenne, with only turning a page, eliminated centuries of discussions—mathematical and metaphysical—on harmonics and accepted the equal

greatest precision that can be imagined” (Mersenne 1957, p. 52). “. . . un autre monochord plus vtile & plus aysé, c’est pourquoy ie le mets icy dans la plus grande iustess que l’on puisse l’imaginer” (Mersenne [1636] 1965, Vol III, Liure I, p. 37).

27. Beaugrand, Jean, (1595–1640). French mathematician close to Mersenne. He referred to him as a “tres-excellent Geometre” (Mersenne [1636] 1965, Vol III, Liure I, p. 37).

28. “. . . sans offenser l’oreille: dont il n’est pas besoin de parelr plus au long,” (Mersenne [1636] 1965, Vol III, Liure I, p. 41).

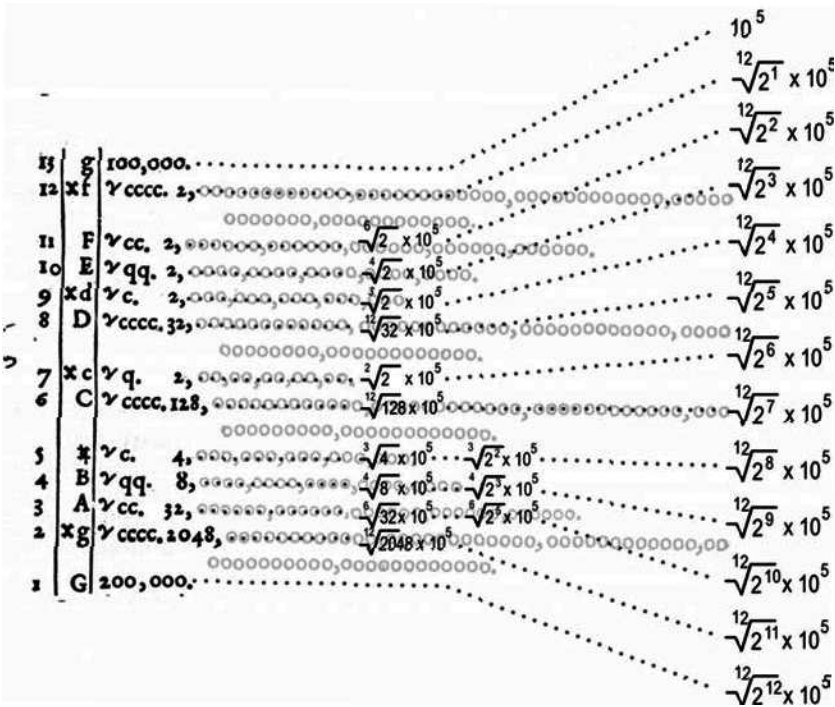


Figure 11.

temperament—as later Western ears will do—on the basis of the audible experience of a monochord, the mathematics of irrationals and the consideration of the string as a sonorous continuum with infinite positions.

Conclusion

Once Mersenne finished his explanation on both monochords, his next Propositions were aimed to quantify the force applied to strings, to count vibrations and to calculate tension considering weights, thickness, length, and all physical characteristics of vibrant string. Mersenne did modern science—mathematical and experimental—in order to construct “the first determination of the absolute vibrational frequency of a tone” (Dostrovsky 1975). This new task was totally independent of the aesthetic phenomenology. Nothing in these final Propositions refers to the pleasure or beauty of sound. Mersenne’s interest was the naked physical fact of the vibrating string and thus the ancient harmony took steps towards modern acoustics. This disregard for sensitive experience—the non-aesthetic

way—could be summarized in his “Deaf Man’s Tablature” which declares that a deaf person can tune the lute, the viol, the spinet and other stringed instruments and get the sounds he would like, if he knows the length and thickness of the strings.²⁹ In a way, we could see in these pages the transition from natural philosophy to early modern science as a process that involves the *an-aestheticization* of the philosophical sentences. Mersenne and his monochords have shown us how to pass from a sentence like this: “the string vibrates pleasantly . . .” to this: “the string vibrates” and no more. Let quantify it. We refer to passing through from qualifying emotions to quantifying perceptions; to make philosophical sentences that have no qualifying adjective. Thus, the old harmonic *ratios* that once told us something about beauty, now will not guarantee anything but the naked fact of vibration. The antique well tuned Universe—from Plato’s *Timaëus* to Fludd’s symbolic monochord—or Kepler’s God who “establishes nothing without geometrical beauty” will vanish to convert harmonic *ratios* into the simple and efficient formula of frequency. Nevertheless, it doesn’t mean that Mersenne has forgotten the aesthetical way; we only want to emphasize that the scientific proposition has been *an-aestheticized*, because, as Needham once said, “If the scientist passes the beauty [of Nature] by, it is only because he is entranced by the mechanism” (Needham 1954, p. 431). As we can see the monochord has served as an empirical base for the birth of this new musical science. There was no dislike in this “disenchantment” of the world. The “entrancing” effect was working and the quantification of musical effects that treated them as physical realities, and not exclusively as aesthetic realities, can be considered one of the great contributions of music to scientific growth in the 17th century. We can affirm that Mersenne’s monochord—using Crombie’s words—has indeed “tailored” metaphysical speculation and quantifiable experience, making them testable and soluble.

Looking for the reasons for musical pleasure, sounds helped to connect the sensitive world to the intelligible one through the material nature of an object: the monochord. In the middle of the 17th century, once the pleasure had been satisfied, the emotions adjectivally qualified and the affection stopped, modern scientific research unfolds. In this process, the monochord has been always present, and in the case of Mersenne’s small wooden box, has simultaneously become—to my surprise—the cradle of modern science and the sarcophagus for harmony’s philosophical ambitions and all its metaphysical derivations.

29. “Un homme sourd peut accorder le Luth, la Viole, l’Epinette, & les autres instruments à chorde, & treuer tels sontz qu’il vodra, s’il cognoist la longueur, & la grosseur des chordes . . .” (Mersenne [1636] 1965, Vol III, Liure III, p. 123).

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