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'OF THE TEMPERAMENT OF THOSE MUSICAL INSTRUMENTS': CONSIDERING TIBERIUS CAVALLO AND THE SCIENTIFIC OBSERVATION OF MUSICAL SOUNDS IN LATE EIGHTEENTH-CENTURY LONDON

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The connection of music to scientific exploration in late Enlightenment London can be considered from various perspectives, perhaps most evidently through the binary of amateur–professional. These two realms intersected within natural philosophical observation, a practice that often served concurrently as entertainment and as study. The development of scientific instruments for the observation of various phenomena appeared in both professional and amateur contexts, contributing to technological growth and research. Natural philosopher Tiberius Cavallo (1749–1809) and his 1788 article on musical temperament ('Of the Temperament of Those Musical Instruments, in Which the Tones, Keys, or Frets, are Fixed, as in the Harpsichord, Organ, Guitar, &c'[1]) provide a captivating example of amateur interest overlapping effectively with the professional domain; as an amateur musician and professional scientist, Cavallo observed equal temperament in both mathematical and aesthetic terms. Consideration of his work promotes a more nuanced view of London as a place where scientific and musical ideas could meet and be 'instrumentalized', emphasizing the city's status as a vibrant arena for the interaction of scientific exploration, artistic endeavour and professional identities. In this sense, Cavallo's work on temperament was not merely a scientific activity; it reflected technological change during a stimulating period of scientific and musical progress in late eighteenth-century London. For example, instrument builders were actively developing ways to improve pitch control and tuning stability, as witnessed by numerous British patents for harp mechanisms, the addition of flute keys and keyboard construction.[2]

As James Davies and Ellen Lockhart have noted, the division in London between art, science and music in the decades around 1800 'was neither effectively policed nor professionally maintained'.[3] This was accompanied by a blurring between levels of specialization and professionalization within musical practice and scientific work. Despite the many differences between them, commonalities clearly did exist between the two. Sibling astronomers William and Caroline Herschel are among those who functioned within both spheres, being professional musicians as well as accomplished scientists whose ground-breaking research was recognized by the Royal Astronomical Society.[4] Similarly, Charles Burney was a professional musician

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1 Tiberius Cavallo, 'Of the Temperament of Those Musical Instruments, in Which the Tones, Keys, or Frets, are Fixed, as in the Harpsichord, Organ, Guitar, &c', *Philosophical Transactions of the Royal Society of London* 78 (1788), 238–254.

2 See *Patents for Inventions: Abridgments of Specifications Relating to Music and Musical Instruments: A. D. 1618–1866*, second edition (London: George Eyre and William Spottiswoode, 1871).

3 James Davies and Ellen Lockhart, 'Introduction: Fantasies of Total Description', in *Sound Knowledge: Music and Science in London 1789–1851*, ed. Davies and Lockhart (Chicago: University of Chicago Press, 2017), 4.

4 William Herschel (1738–1822) is credited with discovering Uranus in 1781 and was active as a composer and musician in the north of England and later in Bath. His sister Caroline (1750–1848) worked with her brother in music and astronomy

and amateur astronomer. In considering Burney's activities, Emily I. Dolan observes that 'to think about music and science is not necessarily to confuse two separate cultures or to reveal secret connections between disparate realms'.[5] In this sense, music and science do not have to be combined within a greater practice; they can exist in harmony as complementary areas of expertise and study. Such a spirit of symbiosis can be applied to Cavallo's work in musical temperament, as his research was conducted between the realms of amateur and professional, musician and scientist.

A native of Naples, Cavallo probably arrived in London in the early 1770s and was elected a Fellow of the Royal Society in 1779.[6] Relatively little is known of his life aside from the scientific studies and lectures that he published and presented throughout his career in London. His research on electricity and magnetism appeared in *A Complete Treatise on Electricity, in Theory and Practice: with Original Experiments* (1777), *An Essay on the Theory and Practice of Medical Electricity* (1781) and *A Treatise on Magnetism, in Theory and Practice* (1787).[7] Notably, Cavallo gave the annual Bakerian Lecture of the Royal Society from 1780 to 1792, covering such subjects as magnetic experiments and observations, 'animal' electricity (muscular motion within living and deceased beings) and pyrometers (a device to measure temperature from a distance).[8] His interest in acoustics, reflected in the article on temperament and a portion of *The Elements of Natural Or Experimental Philosophy* (1803), complemented scientific pursuits in the area of sound during the so-called 'rage' for music in London in the 1780s and 1790s.[9]

As geologist Faujas de St-Fond observed in his memoirs, Cavallo 'displays singular dexterity in performing the most delicate experiments. He has carried electro-meters to such a degree of perfection, as to make them sensible to quantities of electricity inappreciable by ordinary instruments.'[10] Cavallo's work with the electroscope, also known as the pocket electrometer, was arguably his most significant scientific contribution. His electrometer improved upon William Henley's 1770 quadrant electrometer, which consisted of an insulated stem, a semicircular brass scale divided into degrees, a light rod with pith ball and a brass base. The base would be electrified, causing the ball to move at an angle that would then be read from the scale. Cavallo's improvements to the instrument included enclosing the rod inside a glass case to remove the effect of air current, which allowed a more precise result to be read from the scale.[11] In order to work with the relatively insensitive scale available at the time, Cavallo also created an instrument known as 'Cavallo's multiplier',

and was awarded the Gold Medal of the Royal Astronomical Society in 1828. See Constance Ann Lubbock, *The Herschel Chronicle: The Life-Story of William Herschel and His Sister, Caroline Herschel* (Cambridge: Cambridge University Press, 1933).

5 Emily I. Dolan, 'Music as an Object of Natural History', in *Sound Knowledge*, ed. Davies and Lockhart, 33.

6 Paola Bertucci, 'Cavallo, Tiberius (1749–1809)', in *Oxford Dictionary of National Biography*, ed. H. C. G. Matthew and Brian Harrison (Oxford: Oxford University Press, 2004); online edition, ed. David Cannadine, www.oxforddnb.com.

7 Tiberius Cavallo, *A Complete Treatise on Electricity, in Theory and Practice: with Original Experiments* (London: Edward and Charles Dilly, 1777), *An Essay on the Theory and Practice of Medical Electricity* (London: author, 1781) and *A Treatise on Magnetism, in Theory and Practice* (London: author, 1787).

8 Bertucci, 'Cavallo'. See also James Hudson, *Report on the Adjudication of the Copley, Rumford, and Royal Medals: And Appointment of the Bakerian, Croonian, and Fairchild Lectures* (London: Taylor, 1834), 36.

9 Tiberius Cavallo, *The Elements of Natural Or Experimental Philosophy*, four volumes (London: Cadell and Davies, 1803). On the musical 'rage', which was reflected in a surge in subscription concerts, music publishing and instrument sales, see Meredith McFarlane and Simon McVeigh, 'The String Quartet in London Concert Life, 1769–1799', in Susan Wollenberg and Simon McVeigh, eds, *Concert Life in Eighteenth-Century Britain* (Burlington: Ashgate, 2004), 165.

10 Barthélemy Faujas de St-Fond, *A Journey through England and Scotland to the Hebrides in 1784*, volume 1, trans. Archibald Geikie (Cambridge: Cambridge University Press, 2014), 23–24.

11 Robert Bud and Deborah Jean Warmer, eds, *Instruments of Science: An Historical Encyclopedia* (New York: Taylor & Francis, 1998), 220.

which was an electrostatic influence machine used to amplify electric charges to a point where they could be measured.[12]

The notion of measuring the normally unperceivable is noteworthy in relation to Cavallo's work on acoustics and musical sounds, especially his efforts to measure divisions of the octave for a detailed analysis of equal temperament. This is reflected in his use of the monochord for tuning purposes. Cavallo's advancement of scientific instruments that were designed to examine phenomena experimentally helped to move scientific observation out of a naturalistic basis for discussion by allowing detail to be recorded empirically. Various 'philosophical' instruments enjoyed a wide popularity during the late eighteenth and early nineteenth centuries, including early optical devices such as the *camera obscura*. As a result, observations and 'manipulations' of perceived time and space had an impact on art, addressing various issues relating to motion, depth and perception.[13] In this same spirit of observation leading to innovation, but applying his work to sounding bodies, botanist Edward Whitaker Gray (1748–1806) studied the ideal striking-point of the strings on a pianoforte, probably in collaboration with Cavallo.[14] This research fitted into a larger body of experimental work that addressed instrument construction and temperament during the late eighteenth century. London-based builders developed a variety of mechanisms that made possible increasingly smooth transitions between tonalities and evenness of tone, as with the harp and pianoforte patents of Sébastien Érard and the keyed-flute patents of English makers such as Richard Potter.[15]

When considering Cavallo's work in relation to musical sound, his 1788 article on musical temperament is a main point of interest.[16] The concepts addressed here pertain to all fixed-note instruments, including keyboards and fretted stringed instruments such as the guitar. Cavallo's discussion of temperament focuses on string ratio and geometrical progression in equal temperament, how to determine equality from a mathematical perspective and the application of his tuning system to a harpsichord, with the aid of a monochord that he had 'made in a very accurate manner'.[17]

Cavallo offers to show the 'meaning of what is called *the temperament* in a system of musical sounds' with the following conditions in mind: first, that the strings represent the various notes that are played by the harpsichord's keys; second, that the divisions remain unalterable, so that the instrument cannot be modified in the course of performance; and third, that when any one note or division is considered as the key-note (the tonic), its second, third, fourth, fifth and so on must bear their respective proportions.[18] Cavallo also

12 John Gray, *Electrical Influence Machines* (London: Whittaker & Co., 1890), 76–81.

13 Nicholas Wade, 'Philosophical Instruments and Toys: Optical Devices Extending the Art of Seeing', *Journal of the History of Neurosciences* 13/1 (2004), 102–124.

14 Scottish piano builder John Broadwood has been associated with Cavallo and Gray in the study of striking-point on grand keyboard instruments during the 1780s. See David Wainwright, *Broadwood by Appointment: A History* (London: Quiller, 1982), and John Koster, 'The Divided Bridge, Due Tension, and Rational Striking Point in Early Grand Pianos', *Journal of the American Musical Instrument Society* 23 (1997), 5–55.

15 Sébastien Érard, British patent No. 2016, 17 October 1794: 'Improvements in the construction of harps and pianofortes, both large and small, and which improvements may also be applied to all kinds of instruments where keys are used'. This patent includes a mechanism for 'forming' semitones on the harp: 'it [the mechanism] presses the strings so as to reduce the length of the vibrating surface'. *Patents for Inventions*, 28. Richard Potter, British patent No. 1499, 28 October 1785: 'An improvement upon the musical instrument commonly called the German flute', describes construction details to 'tune the flute with other instruments'. *Patents for Inventions,* 16.

16 Cavallo's lengthy and at times overly simplistic discussions 'Of Sound, or of Acoustics' and 'Of Musical Sounds' in the second volume of *The Elements of Natural or Experimental Philosophy* repeat some of the material discussed in the article.

17 Cavallo, 'Of the Temperament', 254. Unfortunately, Cavallo does not describe the mechanism used to activate the string on his monochord. This was probably a plucking-type action with jack and lever, similar to that of the Wardhaugh Thompson monochord patented in 1787 and sold by Longman & Broderip. See Alexander MacKenzie and Kenneth Mobbs, 'The Musical Enigma of Longman and Broderip's Monochord, c. 1790', *The Galpin Society Journal* 57 (2004), 46–52 and 206–207.

18 Paraphrased from Cavallo, 'Of the Temperament', 241–242.

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describes the production of 'musical sounds', limiting his investigation to proportions of length rather than comparing various sounding materials:

> Musical sounds are produced by the vibrations of the sonorous bodies, and they are acuter or graver as the vibrations performed in a given time are more or less in number; so that if a string vibrating 100 times in a second produces a certain sound, and another string vibrating 120 times in a second produces another sound, the latter is said to be acuter, higher, or sharper than the former.
>
> The number of vibrations performed in a certain time principally depends on the thickness, length, and elasticity of the sonorous bodies; but as the simplest sonorous bodies, and the fittest for examination, are those strings which are equal in every other respect, excepting in their lengths, because the number of vibrations, which they perform in a given time, is simply in the proportion of their lengths, we shall consider only those in the present investigation, the number of vibrations performed by other sorts of sonorous bodies being easily deduced from them.[19]

The ability to work with strings of varying length would allow several factors to be established for similar material and instruments in a more general sense. Thus the study of temperament could easily be extended to timbre and volume on any fixed-pitch instrument with consistent mechanism and player's action. The necessity of limiting string equality in all respects except length is a particularly important detail within Cavallo's study, given that various metal alloys and gauges were used throughout keyboard instruments, depending on compass and desired tone. Specifically, assorted irons and brasses (yellow and red) were utilized, sometimes with several metals types appearing in a single instrument for reasons of practicality and timbre.[20] Each metal has unique sounding characteristics, complicating the study of temperament in terms of string length and vibration.

As noted earlier, Cavallo focuses on the monochord and the division of the string based on specific ratios to determine equal temperament. In order to find the exact division of the scale, the string of the monochord is stretched and held between two pins, then plucked while stopped at various points. 'If stopped in the middle, one-half the string will sound the octave . . . ; if two-thirds of the string be caused to vibrate, the sound produced will be the fifth, its length, compared to that of the whole thing, being as 2 to 3, and so of the rest'.[21] He also describes the application of temperament as a system of musical sounds, with the goal of demonstrating the necessity of a systematic approach:

> After a great deal of trouble in adjusting the moveable fret, correcting the divisions, &c. I at last succeeded so well as to render the divisions exact within at least the 300th part of an inch. . . . I had a large harpsichord, with a single unison . . . tuned very accurately by help of this monochord. [In] whatever key the performer played, the harmony was perfectly equal throughout, and the effect was the same as if one played in the key of E natural on a harpsichord tuned in the usual manner.[22]

Cavallo aims to prove that despite the fact that 'writers on harmonics have proposed different temperaments. . . . it will be shewn that the nature of the scale admits of only one temperament capable of rendering the imperfection and the harmony equal throughout'.[23] His subsequent discussion of an actual

19 Cavallo, 'Of the Temperament', 238–239.

20 It is not practical to use a single-string gauge throughout a keyboard instrument's compass because of the excessive length of the bass strings and resulting timbral problems. The string length would have to be doubled for each octave in descent, resulting in unmanageably long bass strings that could touch neighbouring strings when activated.

21 Cavallo, 'Of the Temperament', 239–240.

22 Cavallo, 'Of the Temperament', 254. The meaning of 'E natural' is somewhat unclear, although it is likely that this denotes E major, as opposed to E flat major. The 'usual manner' of tuning would be a variation of meantone temperament, such as the 1799 tuning recipes of Thomas Young. See Young's 'Outlines of Experiments and Inquiries Respecting Sound and Light', *Philosophical Transactions of the Royal Society of London* 90 (1800), 145–146.

23 Cavallo, 'Of the Temperament', 243.

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tuning system makes a particularly interesting point: that we must consult nature, examining by the ear.[24] Cavallo explains string length and proportion in mathematical terms, but recognizes a natural aesthetic preference for equality when dealing with harmonic concordance. This reflects upon musical composition as it relates to performance practice, as key relations and adventurous modulation require a more equal temperament than music that remains within the confines of a single tonality for which an instrument has been specifically tuned. With this in mind, Cavallo recognizes the benefit of non-equal temperament (tuning in the 'usual manner') to give 'greater effect to those concords which occur more frequently in that sort of music'. As he further observes:

> The best keys to be played in are the keys of C, of F, of E flat, of B flat, of G and of D in the major mood, and the keys of C, of D, of A, and of B in the minor mood. Next to those come the less agreeable keys of A, A flat, and E in the major mood; besides those, the rest are disagreeable in greater or less degree, so that out of twelve keys, which, on account of the two moods, *viz.* the major and the minor, become twenty-four, there are hardly fourteen that can be used; and for this reason most of the modern compositions in music are written in those keys.[25]

Although equal-tuning systems were by no means new during the eighteenth century, accurate methods of creating this type of temperament remained an active area of discussion. Cavallo's use of a monochord is an example of natural scientific research, employing the 'philosophical' instrument in its traditional function in the study of string ratio and tuning, as had been done by countless theorists before. It is Cavallo's explanation of the aesthetic qualities resulting from equal temperament that signals a more individualistic stance on the scientific study of musical sound. Despite the scientific rigour of his work, Cavallo ultimately placed aesthetic reason above mathematical concordance, demonstrating an ability to view artistic value as a complement to scientific analysis. His capacity to balance artistic and scientific appraisal reflects his perspective as an amateur musician and professional scientist. Cavallo's discussion of temperament signalled an understanding between art and science, and may be further considered within the development of acoustics and 'musical sound' studies of the late eighteenth and nineteenth centuries, particularly with regard to keyboard temperament, stringing and tuning practices. Ultimately, his work in temperament recognized the importance of a tuning system that was best suited to the keys that were most frequently used, a notion that continues to be discussed within musical practice.

24 Cavallo, 'Of the Temperament', 248.

25 Cavallo, 'Of the Temperament', 252.

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