Intonation Standards and Equal Temperament

In recent decades, most of the scholarly literature has featured unequal temperaments, while paying scant attention to equal temperament. Yet the preference for equal temperament among leading early musicians was substantial because it enabled transposition for instruments built at different pitch levels and permitted all the keys to sound in tune. Their primitive equipment and generally prevailing poor intonation raise the question of whether elaborate mathematical schemes for unequal temperaments could have been implemented successfully. Besides documenting the low intonation standards, described in (among others) Ercole Bottrigari’s Il Desiderio (1594) and Johann Mattheson’s Forschende Orchestre (1721), this essay presents evidence that soloists were not performing flats higher than sharps, as in an unequal temperament, but the reverse, as in modern practice.

Is it possible to draw accurate conclusions about the practical usage of temperaments in bygone centuries without first establishing the quality of the intonation commonly heard? Could complex unequal temperaments have been widely used unless intonation standards were close to our own? Consider wind and brass instruments, which did not begin to achieve modern standards until the mid-nineteenth century and later. Before Theobald Boehm’s groundbreaking efforts in the 1830s, makers of woodwind instruments had always positioned toneholes in an idiosyncratic, unscientific manner. François-Joseph Fétis’s jury report for the Great Exposition in Paris (1867) includes the favorable estimation of Boehm’s mathematical scheme by the organ builder Aristide Cavaillé-Coll, who mentions the haphazard manner in which other makers calculated tonehole location: ‘(…) by the confession of even the best makers whom we have consulted, the pitches [for each note] of their instruments have always been made experimentally and gropingly.’

This explains why good intonation had always been difficult to achieve, especially in ensembles. According to Fétis, Boehm’s complete intonation reform of the flute was ‘one of the most important improvements for wind instruments.’ The latter part of the nineteenth century saw considerable progress in achieving more uniformly even intonation within each instrument.

Compounding the problem in ensembles was the widely varying pitch level among instruments. Because of the large adjustment sometimes required for individual instruments to attain a uniform pitch level in an orchestra, the expedients for adjusting their pitch were not always successful. Not until 1859 was 435 vibrations per second by a Paris government commission; it was adopted as the international pitch standard by the 1885 Stimmtton-Konferenz in Vienna (without the participation of the United Kingdom or the United States). Until instruments attained uniform tonehole positioning and pitch level, intonation problems were inevitable. Writers such as the virtuoso flutist Johann George Tromlitz (Magazin der Musik, 1783) lament this fact:

‘It is usually said that two flutes are seldom in tune and three, never. (…) Since generally no flute is built according to determined principles, they all turn out haphazardly. (…) The first flautist plays according to what his flute and ear are accustomed; the second and third do the same. How can these therefore play together in tune? One would think that the player must himself hear that he is playing out of tune, but no! When he first got this flute, he did indeed hear it, but believed it would pass. It passed all right, but not the flute, only his ear. He became used to it and finally believed that everything would be in tune. (…) I have heard people who called themselves virtuosos and had precisely this error. They knew it not, believed it not, and improved it not; the ear readily spoiled itself.’

Thus it seems unlikely that players could have achieved 1/6-comma intonation (with sharps lower than flats) which today is thought typical for eighteenth-century woodwinds. The quality of intonation in past ages can be judged by their tuning procedures, and accounts from Ercole Bottigari (1594, see below) and Johann Mattheson (1721, see below) describing common situations where the results could only have been excruciating to a modern ear.

Tuning procedures

Our ears, including those of the general public, have been trained by hearing in-tune music every day. Even though a good sense of pitch can be developed in many not born with an outstanding ear, early musicians had none of our resources for training the ear automatically. Their low standards are apparent from the advice that the composer and violinist Francesco Maria Veracini’s Trionfo della pratica musicale offers to mid-eighteenth century directors of professional orchestras:

‘Tuning the orchestra should be done quickly, softly and correctly before beginning the opera overture. We should abandon our predecessors’ pernicious custom of beginning untuned and then making a continuous buzzing while a recitative is being sung. This confounded gun gan gun gan of loud string tuning throughout up until the last chorus (without ever being in tune) disturbs the singers and tortures the listeners terribly.’

2 Johann George Tromlitz, ‘Nachricht von Tromlitzschen Flöten’, in: Carl Friedrich Cramer (ed.), Magazin der Musik, 1.2. Hamburg 1783, pp. 1013-1019 at 1015-1016. ‘Man sagt ingesinnen: zwoy Flöten stimmen selten, und drey niemals. (…) Da gewöhnlich keine Flöte nach bestimmten Grundsätzen gemacht wird, so werden sie alle zufällig bald so, bald so; (…) Ein jeder spielt so, wie er die Flöte hat, und woran sein Ohr gewöhnt ist; der andere und dritte macht es auch so; wie können also diese zusammenstimmen? Man sollte denken, der Spieler müsste es selbst hören, dass er falsch spielte; aber nein! Als er diese Flöte bekam, so hörte er es wohl; er glaubte aber, es würde sich geben; es gab sich auch, aber nicht die Flöte, sondern sein Ohr gab sich; das gewöhnte sich daran, und glaubte endlich, es wäre alles rein. (…) Ich habe Leute gehört, die sich Virtuosen nannten, und eben diesen Fehler hatten; sie wusstens nicht, und glaubten nicht, und verbesserters nicht; das Ohr verwöhnt sich leicht.’

3 Veracini’s treatise, ‘Il trionfo della pratica musicale’ (Conservatorio di Musica Luigi Cherubini in Florence, Signature: 2360 [olim: F-1-28], dated around 1760, although portions may have been written earlier) is reproduced in Jesper B. Christensen, “‘Del modo di guidare colla battuta e senza’: Francesco Maria Veracini über das Dirigieren’, in: Basler Jahrbuch für historische Musikpraxis 24 (2000), pp. 49-69 at 58-59: ‘L’accordo dell’Orchestra debba essere fatto presto piano e giusto, avanti di cominciare l’Overtura dell’Opera, per lasciar il perfido Fideicommissi lasciato dagli Antichi Sonatori, qual è il cominciare scordati, e poi fare un continuo Vespaio nel tempo che gli Interlocutori cantano i Recitativi: e credasi pure quel malodittissimo gun gan gun gan che fanno i Violini e i Violoni accordando forte in fino all’ultimo Coro (senza mai essere accordati), disturba chi canta, strapazza orribilmento chi ascolta.’
Clearly these players were not tuning to a common pitch. A contemporary of J.S. Bach, Veracini worked in locations such as Florence, Venice, London, Düsseldorf, and Dresden, becoming well acquainted with the state of music throughout Europe.

Johann Mattheson’s praise, in his Vollkommene Capellmeister of 1739, of Giovanni Battista Farinelli’s innovative tuning procedure at the Hanover court, too, reveals much about their practice. First, says Mattheson, Farinelli would tune a violin in pure fifths with bow strokes, not finger plucking. Next, he bowed one string after the other to the first violinist until both were completely in tune together. Then the first violinist went to each player separately, doing the same. After tuning, each player had to lay his violin down immediately until all the others had tuned G, D, A and E in just the same way [thereby implying that ‘noodling’ was commonplace during tuning]. And that made a fine effect, declares Mattheson: ‘With us, everyone tunes at the same time and holds the instrument under his arm, which never produces correct tuning.’ As reported by Fétis in his Manuel, tuning each individual separately was still recommended in 1837.5

According to the flutist Johann Joachim Quantz’s Versuch (1752), many professional players were unable to tune pure fifths:

‘nothing would appear easier than to tune an instrument with four strings in fifths, since the fifth is an interval that the ear naturally learns to distinguish more readily than others. Nevertheless, experience teaches that although some experienced violin players or other instrumentalists fulfil their duties in this regard, the majority do not, either because of ignorance or negligence; if each instrument in a large accompanying body were tested separately, it not only would be found that almost every instrument is untrue in itself, but also that frequently not even two or three would be in tune with one another.’

While tuning procedures had improved by the late eighteenth century, the Philosophische Fragmente attributed to Amand W. Schmith (Vienna 1787) call defective tuning the most


5 François-Joseph Fétis, Manuel des compositeurs, directeurs de musique, chefs d’orchestre et de musique militaire, ou Traité méthodique de l’harmonie, Paris [1837], pp. 116-120.


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common and conspicuous error of public performers, particularly when the musician’s ear is so defective that the error can be up to a quarter tone. Its magnitude grates on the ear of even unmusical people. In various places, poor intonation is so ingrained that good tuning is regarded as a minor matter, even though it is one of the most essential requirements. Citing the axiom which calls good tuning half of the playing, he nevertheless knows Gritzköpfe who feel insulted when asked to tune, for they are virtuosi and should not be bound by such trivialities. Schmith’s passage is all the more striking for concerning not lowly ripienists, but soloists in a major musical center.

It was customary for German organists to ‘prelude’ while instruments were being tuned. In his Wichtigste Pflichten (1787), for example, Daniel Gottlob Türk advises playing in a key easy for string tuning (D, A, and G major, or D and A minor). For horns, trumpets, etc., the organist should modulate to the key in which they are made. When all is complete, he modulates to the key in which the music begins. That some organists played only in this key is evident from Türk’s warning: ‘If this key happens to be F minor or Eb major for the instruments, how can the violins, violas and basses be tuned?’ In a not particularly small town, he had heard music in Eb major for which the violins had tuned a semitone too high, but the horns a semitone too low. Only the organ and oboes played in the correct key. Then someone noticed the blunder and one after the other retuned. The modern reader is apt to wonder how one tunes while music is being played.

That tuning standards at the end of the nineteenth century were still far from our own can be judged by remarks from the violinist Carl Flesch, who in the 1890s joined the orchestra founded in Paris by Charles Lamoureux. He recalled that Lamoureux ‘did not mind taking the trouble of hearing each of his 120 orchestra members pass by him one by one before each concert, in order to check, with a violin in his hand, the tuning of every instrument most carefully.’ Probably the greatest catalyst in the transition to modern intonation standards was the advent of recordings, which made it more essential to sing and play in tune. These recordings then served to train the ears of musicians not so blessed.

7 [Amand W. Schmith], Philosophische Fragmente über die praktische Musik, Vienna 1787, pp. 86-87. ‘Von den gemeinsten Fehlern öffentlicher Musiken. Der gemeinst aber auch die auffallendste ist: die unreine Stimmung, besonders wenn das Ohr des Stimmenden so ungeübt in dem vergeblichen ist, dass es auch bis auf einen Viertelton sich verfehlt. (...) Dieser Fehler ist in verschiedenen Gegenand so allgemein, dass man daselbst alle Richtschnur verwirft, und es als eine Kleinigkeit ansieht, da es doch eine der wesentlichsten Erfordernissen in der praktischen Musik ist. (...) ja es giebt wohl einige solche Gritzköpfe welche sich beleidigt finden wenn man sie zum Stimmen bittet, mit der Aeusserung: dass sie als Virtuosen alleine zu stimmen fähig wären, und sich an solche Kleinigkeiten nicht erst binden würden.’

8 Daniel Gottlob Türk, Von den wichtigsten Pflichten eines Organisten, Halle 1787, pp. 136-138: ‘Da hieryd bey das Einstimmen der Instrumente die Hauptsicht [of the Präjudium zur Kirchenmusik] ist, so wurde ich dem Organisten raten, allemal in einem Tone anfangen, worin sich die Violinen u. leicht stimmen lassen. (...) In diesen Tonarten muss sich der Organist eine Zeitlang aufhalten, damit die Musicirenden ihre Saiteninstrumente richtig einstimmen können. Als denn erst geht er, durch eine gutgewählte Modulation, in den Hauptton des Stücks über; allein der Hörner, Trompeten, Pauken u. wegen, muss er noch eine Weile in dem Tone, worin diese Instrumente stehen, moduliren. (...) Ich hörte vor einigen Jahren, an einem nicht ganz kleinen Orte, eine Musik mit an, die einen ganz besonders Eindruck auf mich machte. Die Violistinnen hatten einen halben Ton zu hoch gestimmt, (das Stück gieng aus Es dur) die Waldhornisten aber so viel zu tief; blos der Organist spielte mit den Hoboern aus dem wahren Tone! – Man kann sich leicht vorstellen, wie rührend und erbahulich diese Musik im Anfange ausfiel, bie ein Jeder das Versenhen bemerkte, und Einer nach dem Andern umstimmt.’

Closely related to the problem of poor intonation was temperament, which is necessary because performing a circle of mathematically pure (beatless) fifths leads to a pitch that is almost 24 cents (a ditonic comma) beyond a pure octave. In equal temperament, this excess is removed by subtracting a barely perceptible 2 cents from each fifth, so that every semitone equals 100 cents, and all keys can be used without offending the ear. In all other temperaments, however, the excess is removed unequally, so that some semitones and whole tones are larger than others. Mathematically pure intervals were prized by those theorists promoting unequal temperaments – hence the frequent usage of the term ‘purity’ – and attaining this goal took on the aura of a mathematical challenge. Certain theorists held equal temperament’s lack of any pure interval but the octave to be a grave shortcoming. Was this premise based on the actual sound of equal temperament or was it a paper argument by those committed to the belief that mathematically pure intervals are superior? For example, Georg Friedrich Tempelhof (1775) stated that equal temperament is the worst possible one because no interval but the octave is completely pure.10

Because the unequal temperaments utilize whole tones and semitones of variable size (the larger ones are sometimes called ‘major’ and the smaller, ‘minor’), transpositions for ensembles will be out of tune. For example, when an instrument is pitched a whole tone above the others, its part has to be transposed down a whole tone. Therefore, the major and minor semitones fall at different locations than they do for the other instruments. Equal temperament, of course, removes this barrier.

Ercole Bottrigari’s Desiderio (Venice, 1594)
Ercole Bottrigari’s Il Desiderio, overo De’ concerti di vari strumenti musicali, published in 1594, concerns principally intonation.11 A mathematician, architect, music theorist, composer, and poet who lived in Bologna and Ferrara, he was personally acquainted with Gioseffo Zarlino and Torquato Tasso. Taking the form of a conversation between the master Alemanno Benelli and the learner Gratioso Desiderio, Bottrigari’s book begins with the latter’s disappointment about a large concert of some forty participants he has just heard. In all such concerts, he has never experienced the expected pleasure. Picture them playing not with the refinement we expect, but with tremendous clamour. According to the virtuoso cornettist Luigi Zenobi (1601), instrumentalists restrain their volume in chamber music for princes; but in church music and large concerts, everyone plays as loudly as possible, which creates a great din and hides all the blunders and poor intonation.12 Having worked at the Ferrara court from 1589–1597, Zenobi probably knew Bottrigari.

The concert Gratioso describes included a large harpsichord, a large spinet, three lutes, many violi, many trombones, two rebecs, large flutes, a large double harp and a lyre accompanying a large number of good voices. But instead of celestial harmony, he hears offensive confusion and discord and wonders if something is wrong with his ear. The answer, responds Alemanno, is that very often the instruments are not tuned together properly. Gratioso finds this hard to believe because all the musicians are excellent artists whom he knows well, and each one has the ability to be himself a director. Noting that discord can also arise from unstable gut strings and differences in individual perceptions of pitch, even among virtuosi, Alemanno declares that ‘it frequently happens that a string

11 Ercole Bottrigari, Il Desiderio, overo De’ concerti di vari strumenti musicali, Venice 1594, pp. 3-12.
seems low to one player and high to another, resulting in confusion. Thus just one person should tune all the instruments.'

Discord is also produced, he continues, by trying to combine instruments that are tempered differently by their structure or custom.

In Bottrigari’s text, keyboards and harps, which have unequal semitones and are tempered according to the individual practice of their builders and tuners, are called stable (tutto stabili) instruments because they cannot be changed after tuning. The stable but alterable (stabili, ma alterabili) instruments include wind instruments such as flutes and cornets, whose holes are bored by ear, producing considerable variation in the size of semitones. Accomplished players can alter pitch somewhat by the manner of blowing. Also classed as ‘stable but alterable’ are viols and lutes, whose players can press their frets (which produce equal temperament) a little higher or lower to alter pitch somewhat. The completely alterable (tutto alterabili) instruments include trombones and string instruments, which can adjust pitch to conform to instruments of the first two groups.

Alemano cites an advantage of the fretted instruments: their equal semitones enable transposing up or down a semitone or whole tone without offending the ear, but this is unsatisfactory with the unequal semitones of a ‘stable’ instrument. Although the ‘stable but alterable’ instruments could alter pitch to a degree, this alteration had to be quite limited — and most players lacked today’s keen ear and well-developed technique to accomplish it. Alemano stresses that the lutes and viols cannot combine perfectly with the stable instruments because of the latter’s variable semitones. According to Vincenzo Galilei (1580), the lute’s tuning is much closer to perfection than that of the keyboard instruments — an observation suggesting that equal temperament was highly regarded by leading thinkers. Around 1580, Giovanni de’ Bardi was amused by musicians struggling to tune a lute or viol with a keyboard instrument. In recommending that consorts not combine fretted and keyboard instruments, he adds: ‘Until now this highly important matter has gone unnoticed or, if noticed, unrestrained.’ Thus Bardi is another witness to the fact that most musicians were unaware of serious discordance.

In Alemano’s experience, those responsible for arranging the concerts do not understand the differences among the instruments; otherwise, they would not make such disharmony by combining unsuitable instruments. Noting Aristotle’s advice about accompanying the voice with just a lyre or tibia because adding more instruments obscures and almost entirely destroys the melody, he declares that instruments from all three groups should never be combined, for it produces the greatest discordance. Gratioso is astonished that so many men of sound judgment have never been aware of this fact.

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13 Bottrigari, Il Desiderio, p. 4: ‘tutti questi uiutuosi (...) non sono di un medesimo giudizio, & di un medesimo orecchio & questo si vede assai volte, che ad uno sonatore pare, che una uoce, ò suono di una corda di uno strumento sia rimessa, ò bassa, & ad un’altro sonatore pare, che sia tesa, ouer alta, talché come questa cosa si uiene à mescolare con varie orecchie, & uarij giudicij presto presto si dà in una confusione, però è necessario, che un solo sia, il quale accordi ogni cosa.’

14 Bottrigari, Il Desiderio, p. 8: ‘Ma questo [the offensive dissonance when combining transposed instruments] non auienne nel Lauto, & nelle Viuole: perchè hanno in ogni luogo il semituno eguale, & possono sonare vn tuon più alto, vn tuon più basso, & un semituno più alto, & un più basso, che non dà noia al senso.’


17 Bottrigari, Il Desiderio, pp. 11, 12: ‘Ma perch’io tengo, che non si possa fare se non con grandissima disunione, & tal qual mi siète venuto dipingendo quella; che apunto hauete udita hoggi; però consigliarei sempre à non
Turning to keyboard tuning, Alemanno calls it a trial and error approach. If two different keyboards of the same size and quality were to be tuned by two equally skilled masters in separate locations, and if the tuning started from a note perfectly in unison between the two, he greatly doubts that after tuning any other unisons would be found. If the same master tuned both instruments in separate locations, he adds, again only the first unison would be in tune on both.\(^{18}\)

From Bottigari’s account, we can conclude (1) that musicians disagreed about what sounded in tune and few were capable of tuning properly, (2) that prominent musicians were unaware of major intonation defects, (3) that keyboard tuning produced inconsistent results, and (4) that wind instruments were tempered by ear without uniformity. In his day, in-tune execution was likely achieved mainly by a few soloists with exceptional ears, accompanied preferably by a single instrument. Very slowly, over the next three hundred years intonation standards gradually improved, with the bulk of the improvement taking place in the nineteenth century.

Other writers tell us that even violinists, with completely alterable pitch, found it difficult to play in tune with keyboard instruments,\(^{19}\) probably because flats are higher than sharps in the unequal keyboard temperaments; thus $E_b$ is higher than $D\#$. Because this runs counter to the ear’s expectation that sharps be higher than flats, it requires particular skill and determined effort to execute. Early musicians’ ears were no different: the Alsatian Anton Bemetzrieder’s Lettre (1773) observes that string teachers tell students to raise the sharps and lower the flats as much as they can. Skilled violinists put $C\#$ as near to $D$ as possible; the distance they put between $C$ and $D\#$ is no more than a shadow.\(^{20}\)

**Johann Mattheson’s Forschende Orchestre (Hamburg, 1721)**

Johann Mattheson, in his Forschende Orchestre of 1721, criticizes the poor intonation resulting from the fact that the pitch level of German organs (called *Chorton*) was usually a whole tone above that at which most instruments played (called *Camerton*). Thus the organ part had to be transposed down for playing with instruments, so that when the latter play in the key of $G$, the organ plays in $F$. When these organs were tuned with the variable semitones of an unequal temperament, the organ might be playing a major semitone while the instruments play a minor one. This produced cacophony of grand proportions, as Mattheson indicates:

‘Consider the abomination when instruments at *Camerton* pitch, such as horns, flutes, bassoons, etc., sometimes have to play with others at *Chorton* pitch, so that one

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\(^{19}\) Hubert Le Blanc, *Défense de la basse de viole, Amsterdam* 1740, pp. 53-54.

\(^{20}\) Anton Bemetzrieder, Lettre (...) à M. le baron de S’**, *concernant les dièzes et les bémols*, Paris 1773, p. 3: ‘Déjà des Maîtres recommandant à leurs Écoliers de monter les dièzes tant qu’ils peuvent; ils disent, descendez vos bémols tant que vous pouvez. D’hables violons s’exercent à prendre l’ut dièze au plus près du ré; la distance qu’ils mettent entre l’ut & le ré bémol n’est bientôt plus qu’une ombre.’
group or the other must be transposed. Is that sound any different than the composer or cantor portraying the quarrel of the dogs over Jezebel’s fallen body?  

This unavoidable discord is why Mattheson favored universal tempering of instruments. Think what happens, he continues, when a horn at Cammerton pitch plays G A [a minor tone of 182 cents] in unison with an organ at Chorton pitch playing F G [a major tone of 204 cents]: ‘And that should be in tune? (…) But many have ears and hear not’ – an indication of the extent to which false intonation was tolerated. The difference between 182 and 204 cents constitutes an entire syntonic comma. (These cents values are theoretical; in practice, they could vary widely according to the temperament scheme utilized and the tuner’s skill. Thus the divergence might be even greater than a comma.)

Yet Mattheson had to struggle against theorists and instrument builders who did not hear anything amiss with their unequal temperaments under these circumstances. They relied on their calculations, which told them that equal temperament had no pure interval except the octave. Ergo, they reasoned, it had to be defective, for the goal was to obtain some mathematically pure intervals. They did not realize that the tiny amount each fifth is narrowed is scarcely perceptible to the human ear. In citing Johann Georg Neidhardt’s 1706 calculation for equal temperament, Mattheson laments that instruments continue to torment the ear with discrepancies between major and minor tones and semitones. ‘If, as is to be wished,’ he continues, ‘this equal temperament were used on all the instruments, and particularly the organ, the ear would no longer be so greatly assaulted.’ A still earlier advocate of equal temperament was Andreas Werckmeister.

**Equal temperament**

Because of its ability to solve problems cited above, leading musicians favored equal temperament long before the time generally accepted today. In recommending a method for improving the defective intervals to make them all fully consonant, Johann Joseph Fux’s *Gradus ad Parnassum* (1725) says that ‘an almost imperceptible portion is taken away from one part [the fifth of each octave] and applied to the other part [the fourth], thus abolishing the need for extra keys. Therefore, our music is freed from defective intervals, as from a prison, and has extraordinarily free rein to go now here, now there.’

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22 Mattheson, *Das forschende Orchester*, pp. 426-427: ‘Wenn Z. E. das Waldhorn, in seiner *transponirt* Melodie g. a. bläset, und also per tonum minorem procedit; so schnarret das Chortönige Regal dagegen f.g. welches *tonus major*; und das soll sich *accordiren*? (…) Viele aber haben Ohren, und hören nicht.’

23 Mattheson, *Das forschende Orchester*, p. 438: ‘Kämme es dereinst, wie zu wünschen, mit einer solchen gleichschwebenden Temperatur auf allen Instrumenten, insonberedig auf Orgeln, zum Stande, so würde das Gehör (…) nicht mehr so viel beleydiget werden.’


Fux has thus prescribed equal temperament, in which all the fifths are flattened ever so slightly, while the fourths become correspondingly enlarged. In 1742, J.S. Bach’s former pupil Lorenz Christoph Mizler translated Fux’s treatise from the Latin, but abstained from adding any commentary in this location, because, he says, the work is written primarily for practicing musicians, who are not served by discussions of a theoretical nature.\(^\text{26}\) If equal temperament had not been the norm, Mizler surely would have had to comment. Bach owned a copy of this work, and his music implies liberation from the prison Fux describes, for it nearly always modulates into keys requiring equal temperament.

When information enters a musical dictionary, it has usually attained a degree of general acceptance. According to tuning directions in the anonymous _Kurtzgefasste musicalisches Lexicon_ (Chernitin, 1737), all fifths are tuned ever so slightly flat, while all major thirds are tuned a little sharp – which is the prescription for equal temperament.\(^\text{27}\) Equal temperament is required for the transposing keyboards that Bemetzrieder describes in an earlier _Lettre_ (1771):

‘An entire nation [probably Germany, BJ], which certainly cannot be said to lack an ear, divides the octave into twelve equal intervals. Consequently, it builds harpsichords in which, by pushing the keyboard a notch toward the right or left, the same key can strike B or C\(_4\) in order to raise or lower the instrument a semitone and instantly put it in tune with the wind instruments. (…) Write the same piece of music in the keys of F\(_b\) and G\(_b\). Give one of them to a virtuoso violinist and the other to a virtuoso harpsichordist, and you will find them in tune, if the harpsichord is tuned with equal semitones.'\(^\text{28}\)

Georg Andreas Sorge intended his _Gespräch_ (…) _von der_ (…) _Temperatur_ (1748) to raise awareness about the inadequate tuning of many organ builders, including the noted Gottfried Silbermann, whose ear, said Sorge and others, was no match for his construction

\(^{26}\) J. J. Fux, _Gradus ad Parnassum, oder Anführung zur regelmässigen musikalischen Composition_, trans. Lorenz Christoph Mizler. Leipzig 1742, pp. 52 and 53n. ‘Da man aber gesehen, dass diese [unequal] Einrichtung der Tasten sehr viel Beschwerlichkeit verursacht, und man doch darauf bedacht war, wie bey dem Mangel der Intervallen solche könten erweitert, und die vollkommenen Consonanzen erhalten werden, hat man den Ton und halben Ton in zwey gleiche Theile zu theilen sich bemüht. Da man aber erfahren, dass solches in Zahlen nicht angehet, ist das Ohr zu Hülfle genommen worden, indem man von dem einem Theil einem fast gar nicht mercklichen Theil weggenommen, und dem andern zugesetzt, durch welche Bemühung man die Beschwerlichkeit der vielen Tasten aufgehoben, und es dahin gebracht, dass man bey unserer Musik, welche nun von der Armuth der Intervallen, als einem Gefängniss, befreyet worden, ein ungemein weites Feld vor sich hat, da man bald da bald dorthin sich begeben kan.’

\(^{27}\) _Kurtzgefasstes musicalisches Lexicon_. Cherninitz 1737, ‘Stimmen der Instrumenten’, p. 358: ‘man alle Quinten ein gar weniges unter sich schweben lassen muss, hingegen lässt man alle Tertias majores, den obern gegen den untern Clavein, ein wenig in die Höhe schweben, da man denn hernach einem und dem andern bald nachhelfen kan.’

\(^{28}\) Anton Bemetzrieder, _Lettre_ (…) _à MM. ***, musiciens de profession, ou Réponse à quelques objections_. Paris 1771, p. 46: ‘il y a une Nation toute entière qui certes ne passe pas pour manquer d’oreille, & qui prescrit le partage de l’octave en douze intervalles égaux; en conséquence elle construit des clavecins où le clavier poussé d’un cran vers la droite ou vers la gauche, la même touche peut faire résonner la corde si ou la corde ut dièze; hausser ou baisser l’instrument d’un demi ton, & mettre tout-à-coup le clavecin d’accord avec les instruments à vent. (…) écrivez le même morceau de musique en fa dièze & en sol bémol. Donnez une des copies à un Virtuose Violon & l’autre à un Virtuose Claveciniste; & vous les trouverez d’accord, si le Clavecin est accordé par sémi-tons égaux.’
skill.\textsuperscript{29} According to Sorge (who promoted equal temperament), they persist in their faulty practice because they cannot play a keyboard themselves and do not understand key relationships. They even tell organists not to play in the less common keys. As a witness to the fact that ‘today’s practice requires all twenty-four keys to be equally usable and in good tune,’ he names J.S. Bach. In his \textit{Zuverlässige Anweisung} (1758), he describes the progress made by equal temperament:

‘Not only most of the practicing musicians, but also various organ and instrument builders acknowledge that no tuning is better than when one can have equal purity in all keys.’\textsuperscript{30}

In this context, ‘purity’ means ‘in tune’. Despite favoring equal temperament themselves, Sorge and other theorists presented also unequal temperaments for those who believed that a temperament had to have some mathematically pure intervals.

In dedicating his \textit{Anweisung} (1756; Figure 1) for tuning equal temperament to Carl Philipp Emanuel Bach, the keyboard builder Barthold Fritz confirmed C.Ph.E. Bach’s preference for equal temperament. Perhaps Bach lent his name and reputation to this project in order to support efforts for improving the tuning of keyboard instruments. ‘Only that tuning is best,’ says Fritz, ‘in which all the major and minor keys can be played with equal purity, and the ear can detect no difference in the key’s purity, whether playing in the keys of C or C\# in F or F\# in G or G\#.’\textsuperscript{31} His book, however, is not a completely reliable technical exposition of equal temperament, and Sorge finds Fritz much more skilled in tuning equal temperament by ear than in describing its properties accurately in writing.\textsuperscript{32} But its tuning instructions were influential; for example, Friedrich Wilhelm Marpurg’s \textit{Die Kunst das Clavier zu spielen} (Berlin, 1762, p. 3) recommends them to teachers, for he regards equal temperament as essential.

The importance of equal temperament in certain areas of Germany can be judged from Jakob Adlung’s \textit{Musica Mechanica Organœedi} (1768) – Germany’s most significant eighteenth-century work about organ building – which assumes that tuning will be in


\textsuperscript{31} Barthold Fritz, \textit{Anweisung, wie man Claviere, Clavecins, und Orgeln nach einer mechanischen Art, in allen zwölf Tönen gleich rein stimmen könne}, 2\textsuperscript{nd} edition, Leipzig 1757, p. 2: ‘nur diejenigen Stimmung eines Clavers die beste sey, nach welcher man in allen zwölf Tönen moll und dur gleich rein spielen könne, und keinen Unterschied, so viel die Reinigkeit der Töne betrifft, im Gehöre vermerket, ob man aus c, oder cis, aus f, oder fis, aus g, oder gis spielt.’

\textsuperscript{32} Johann Andreas Sorge, \textit{Zuverlässige Anweisung}, pp. 2ff.
equal temperament and includes instructions. Published posthumously, and thought to have been written in the 1720s, it was prepared for publication by Johann Friedrich Agricola, who had studied with J.S. Bach.

**The numbers or the ear as judge?**

While intricate temperament schemes have been advocated today as correct for eighteenth-century music, their only tuning aid was the monochord. Its limitations were shown in a contest to find who could tune equal temperament better — Johann Nicolaus Bach (J.S. Bach’s uncle) by ear or Neidhardt with a monochord. Nicolaus Bach’s ear won the day and enabled a chorale to be played in the key of B♭ minor. According to Adlung, Neidhardt’s calculations were correct, but the monochord was inadequate because it is difficult to tune a pipe to a vibrating string. Moreover, the monochord’s string is unstable and needs constant checking with the reference pitch. When the string is struck, the pitch is somewhat higher than when it is almost at rest, so it can never have even beating. With the intonation standards documented above, it is unlikely that any but the keenest ear could have executed elaborate temperaments.

Whereas those early theorists who favored unequal temperaments seem to have assumed that an in-tune interval is mathematically pure or nearly so, modern studies demonstrate that the human ear has no predilection for pure intervals (except the octave) and that the size of an interval can vary dramatically while still sounding in tune. The false correlation between in-tune intervals and mathematical purity is the crux of the matter. Later in the eighteenth century, it began to dawn on some theorists that their calculations

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were not what was being performed. In his *Elementi* (1791), the violinist and orchestra leader Francesco Galeazzi observes with some surprise that violinists were playing a small semitone between leading note and tonic, rather than a large one.\(^{36}\) What had changed was not practice, but perception. With even virtuosos having poor intonation, as reported above, and instrument toneholes still being bored haphazardly in 1867, it is implausible that anyone sang or played a non-keyboard instrument accurately according to an unequal temperament or just intonation. According to Adlung, the various temperament calculations gave rise to the question: ‘Whether the ear or the numbers should judge if music sounds in or out of tune.’\(^{37}\) A supporter of equal temperament, he favored the ear.

The other argument brought against equal temperament was that it made all keys sound the same, thereby removing their ‘key character.’ Among non-believers in this theory was J.S. Bach’s colleague Johann David Heinichen whose *Generalbass* (1728) observes that even if these imaginary properties had any validity, the slightest change of temperament would destroy them, not to mention the changes caused by having to combine instruments at *Chorton, Cammerton*, French and Venetian pitch levels.\(^{38}\) The tuners are ‘never accurate’, he declares—a assertion of some importance in this matter, for we have assumed standards close to our own.

In temperament, actual practice differed greatly from what some theorists propounded. According to Domenico Scorpione’s *Riflessioni armoniche* (1701), the tuning of keyboard instruments does not correspond to the theory in force. In theory, the semitones are unequal, but in practice they are always equal; any difference which may be found between semitones is so small that it can scarcely be detected by the ear.\(^{39}\) Since early theorists had no equipment for testing the accuracy of their suppositions, Scorpione’s observation is more than plausible.

Before the twentieth century, intonation was often problematical. From the above documentation, there seems little reason to doubt the accuracy of Robert Philip’s findings:

> ‘Early recordings make it clear that standards of accuracy, tuning, clarity and precision were generally lower in the early twentieth century than they are today, and there is no reason to suppose that they were higher through the nineteenth century.’\(^{40}\)

The further back in history we go, the worse the intonation standards are likely to have been. A formidable task awaited those musicians working to improve them. This is the

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\(^{38}\) Johann David Heinichen, *Der Generalbass in der Komposition*, Dresden 1728, p. 84: ‘Ja, wenn auch diese *proprietas Imaginariae* an sich selbst ihre Richtigkeit hätten, so würden doch selbige bey dem geringsten Unterscheid der gebräuchlichen temperaturen, (worinnen die Instrument-Stimmer niemahls accurat eintreffen) noch mehr aber bey Veränderung des Chor- Cammer- und Französischen, *item des extravaganten Venetianischen* ton alle Augenblick Schiffbruch leiden.’ According to Athanasius Kircher’s *Musurgia universalis* (1650), Venetian pitch was a major third lower than that of Naples, while Florence and Rome were in between.


background against which to measure the assertions of early theorists and mathematicians who promoted unequal temperaments.

Equal temperament is the best solution not only for J.S. Bach’s harmonically complex music, but also for the situations in which he worked, where he almost always had to transpose orchestral parts because of differing pitch levels. Individuals close to him – his son Carl Philipp Emanuel, his former pupil Mizler, and Sorge (like J.S. Bach, a member of Mizler’s society) – supported equal temperament either explicitly or implicitly. Just as Adlung and many others who preferred equal temperament thought that the ear, not numbers, should decide whether a temperament was in tune, so too did C.Ph.E. Bach. After Fritz’s equal-temperament tuning manual was published, Bach wrote to him, observing that it provides everything necessary for tuning and is incomparably more useful than the many calculations with which some have racked their brains, because this type of instruction is only for a very few, but Fritz’s is for everyone, not excepting even the theorists, because theirs, too, depends on the ear’s verdict.\textsuperscript{41} From Adlung’s and Bach’s remarks, it is clear that unequal temperaments were presented not for artistic reasons involving the actual sound produced, but from the faulty assumption that some mathematically pure intervals were essential, regardless of the harm this caused the other intervals. Theorists such as Werckmeister, Neidhardt and Sorge favored equal temperament themselves, yet provided circulating temperaments for those holding this belief, hoping to encourage them to abandon the old quarter-comma meantone for an improved temperament that satisfied the desire for some pure intervals.

\textsuperscript{41} Fritz, \textit{Anweisung}, 2\textsuperscript{nd} edition, Vorbericht: ‘und dass insbesondere meine Anweisung zum Stimmen bey dem berühmten Hrn. Bach zu Berlin Beyfall gefunden, als welcher in seinem an mich erlassenen Schreiben sich darüber dergestalt geäussert hat, dass in meinen wenigen Bogen alles gesagt sey, was nöthig und möglich gewesen, und dass solche ungleich mehrern Nutzen stiffen würden, als die vielen Ausrechnungen, womit sich mancher den Kopf zerbrochen hätte, indem diese Art von Anweisung nur für sehr wenige, die meinige aber für jedermann sey, selbst die Berechner nicht ausgenommen, weil diese von dem Ausspruche des Gehörs so gut als andere abhiingen.’