Improving Intonation

by Benjamin Whitcomb

Intonation is one of the very most important aspects of playing a bowed string instrument well. It is useful to divide a discussion of intonation into three parts: the science of intonation, the various types of intonation problems, and ways to improve intonation. The discussion of the science of intonation is fairly technical, but please bear with me. This is one of those areas in which, I believe, the better we understand how the concept works, the better we will deal with it in the long run.

The Science of Intonation

The first step in understanding intonation is simply knowing what the term means. In its simplest definition, intonation means that sometimes a note sounds to us like it should be higher or lower in pitch within its musical context. Why is this the case? Theorists are always trying to answer this very difficult question. Many great minds in many different fields and many different centuries have tried to answer it, and to this day people are still working on it. Some of the most likely possible sources for an explanation include the following: the overtone series, the sensation of "beats" that the ear experiences with certain collections of pitches, and "small integer prime ratios" between the frequencies of the pitches involved.

For the purposes of this discussion, we will limit ourselves to the intonation of the 12 pitches that the octave is traditionally divided into in Western music theory. A discussion of intonation beyond this framework takes us a bit too far afield. If you are interested in studying the topic of intonation beyond this framework, I would refer you to the articles and books listed under this subject in the bibliography.

It is important to understand that the ear is a relativist. A single pitch in isolation cannot be said to be in tune or out-of-tune. When we speak of intonation, we're talking about the way that the ear compares one pitch to another. That is to say, it is not the absolute frequency of pitches that determines whether or not they sound in tune, but rather the ratio between the frequencies of the pitches.

Here is what we do know about intonation: for any given interval (i.e., pair of pitches), there is a small range of pitch ratios that we would all consider to be "in tune." The ear, like all of our senses, is limited in its ability to discern variations in pitches, or likewise in intonation. This limit is called the "limit of discrimination." In the case of simultaneous (harmonic) intervals, this ideal ratio tends to conform to what is known as "just intonation." The table below shows the ratios involved in just intonation, equal temperament, and Pythagorean intonation, which are the three most well-known tuning systems for Western music. (Equal temperament is the tuning system that is used most often today, especially for

fixed pitch instruments such as keyboards, in which all half steps are of equal size. Pythagorean and just intonation are tuning systems that are based on frequency ratios, the former using only the numbers 2 and 3 in its prime factorizations, and the latter using the numbers 2, 3, and 5.)

A Comparison of Just Tuning, Pythagorean Tuning, and Equal Temperament

Interval	Pythagorean Tuning		Just Tuning		Equal Temperament
	ratio	decimal	ratio	decimal	decimal
m2	1 / 1	1.054	16 / 15	1.067	1.059
M2	256 / 243	1.125	9 / 8	1.125	1.123
m3	9 / 8	1.185	6 / 5	1.2	1.189
M3	32 / 27	1.266	5 / 4	1.25	1.26
P4	81 / 64	1.333	4 / 3	1.333	1.335
Tt	4 / 3	1.405	45 / 32	1.406	1.414
P5	1024 / 729	1.5	3 / 2	1.5	1.498
m6	3 / 2	1.580	8 / 5	1.6	1.587
M6	128 / 81	1.688	5 / 3	1.667	1.682
m7	27 / 16	1.778	9 / 5	1.8	1.782
M7	16 / 9	1.898	15 / 8	1.875	1.888
P8	243 / 128	2	2 / 1	2	2

In the case of successive (melodic) intervals, this ideal ratio varies considerably depending on the context. Melodic intervals, especially larger ones, tend to be stretched (increased in size) compared to harmonic ones. Melodic intervals also tend to be exaggerated within categories (or sizes) , in order to help the ear differentiate between them.. That is to say, there is more distance between a major third and a minor third than between a minor third and a major second, because major thirds and minor thirds are within the same interval category (i.e. they are both thirds). Fixed-pitch instruments have to choose one fixed ratio for each pair of pitches. Variable-pitch instruments have the ability (and the responsibility!) to change the ratio as the context changes (such as from harmonic to melodic minor or from one interval category to another).

To show yourself just how much a pitch needs to be altered to sound in tune, try playing first finger E on the D string in two ways: as part of a double stop against the open A string and as part of a double stops against the open G string. Notice how much you have to alter the location of first finger in order to eliminate the beats in each of these intervals.

Studies of the intonation of concert violinists and singers show that their system of intonation doesn't match any tuning system, which shouldn't surprise us, given that real music consists of different degrees of melodic and harmonic factors at any given time. However, their intonation is never too far from equal temperament or just intonation.

Another way to think about this is as follows: if someone were to play a passage using intonation that precisely matched either the system of just intonation or equal temperament, that passage would not sound out of tune as such. (Does a pianist ever sound out of tune, assuming the piano was tuned well and recently?) I think this is why many string players are perfectly content emulating equal temperament: their primary goal with respect to intonation is to be "not out of tune" all of the time.

Another important thing to understand about the ear is that its sense of intonation discrimination exists in a hierarchy: The ear is not equally sensitive to the same degree of intonation for all intervals. Concerning scale degrees in tonal music, the ear is most sensitive to the intonation of the tonic and the dominant. Concerning isolated intervals, the ear is sensitive to their degree of intonation in proportion to the interval's degree of consonance. That is to say, the ear is most sensitive to the intonation of unisons and octaves, followed by the P5 and the P4, followed by the thirds and sixths, and so on through the dissonant intervals.

Knowledge of the ear's intonation hierarchy is very important for musicians who play variable-pitch instruments. Fingerings can be chosen to favor the intonation of scale degrees one and five and the perfect intervals. Also, increased attention to and efforts to improve the intonation of the scale degrees and intervals can pay off in spades.

The Types of Intonation Problems

There are three basic types, or sources, of intonation problems: conceptual, aural, and tactile/physical. In the case of conceptual or aural problems, the best solution is to study theory and ear training. Useful ear training exercises include melodic dictation and sight singing. Most any sight singing book will do, and nowadays there are many quality ear training software programs available. No matter how good your ears are, you will always benefit from improving them further. You must learn to imagine precisely what a given pitch should sound like before you play it. In the case of tactile/physical problems, the solution depends on where the intonation discrepancies occur.

Locations of (Physical) Physical Intonation Problems

This is what most discussions of intonation address, and it is often what we mean when we talk about improving our intonation. Intonation problems can exist:

1. Within a position. This is typically caused by inaccurate finger spacing or an unbalanced hand.
2. Across positions: small shifts. This is often caused by an unbalanced hand, too much or uneven pressure during a shift (resulting in a finger getting "run over"), or a hand that rotates and thus does not stay parallel to the fingerboard.
3. Across positions: large shifts. In addition to the possible intonation problems for small shifts, this type of problem may be caused by an inflexible shoulder or elbow, or by an elbow that is not set properly to clear the side of the instrument before a shift to the higher positions.
4. Across strings. This can be caused by a lack of mobility in the left elbow.
5. During vibrato. This tends to be caused by a vibrato that is too wide or uneven, one that drifts, or one that goes above the given pitch.
6. More than one of the above. In addition to the solutions above, this situation may indicate that the ear needs to be improved.

Useful Techniques to Improve Intonation

Below is a list of some ideas that may help you to improve your intonation. Many solutions apply to more than one of the problems listed above.

For all types of problems:

- Listen for the extra ring that you get from the sympathetic vibrations of the other strings. This works much better for some notes than for others, but works to a degree for all pitches. After a while, you will learn what the ring "signature" is for all 12 pitch classes. (A pitch class is all of the pitches that share the same name, regardless of their octave.)
- Try to anticipate and actually feel in your hand the exact pitch that you are about to play, and whether or not it will be in tune, just before you play it.
- Record yourself, and mark notes to yourself on a copy of your music while you listen to the recording. Most of the time we listen much better and more objectively when we're not playing.
- Practice dividing a half step into as many smaller parts as you can-into as many as 16 or more parts! First, divide a half step into two parts, then into four parts by splitting each of the quarter tones in half, and so on.
- Play problematic passages on a different instrument (such as a piano, or with your voice) or in a different octave.

Within a position:

- Play entire passages in double stops with adjacent open strings, or with stopped notes on other strings.

For shifting:

- Take each of the 12 simple intervals in turn as a double stop, and transpose each one chromatically through an octave
- Play problematic passages in all 12 keys.
- Practice playing all of your shifts as audible shifts, first slowly, then fast, then gradually quieter until the shift becomes inaudible.

For vibrato:

- To make sure your vibrato is not affecting intonation, practice both with and without vibrato while watching a chromatic tuner.

A chromatic tuner is a valuable tool that can be misused. It should be used to help calibrate your own internal tuner, not to substitute for it. Try setting the tuner just outside of your peripheral vision. When you arrive on a note that sounds questionable (in terms of intonation), glance over at the tuner to see what it thinks of the pitch. Before you look at the tuner, try to predict exactly where the needle is pointing!

Some people use tuners quite often, and always strive to play every note such that the needle is straight up and down. Remember, if you do this, you are calibrating yourself towards equal temperament. I hate to see people "correct" what the tuner says is an out-of-tune pitch, when the pitch that they were playing actually sounded better in tune than the equal-tempered pitch. The value of these machines is that they can help you learn to tune consistently. In other words, if you want the leading tone to be 10 cents sharp in a particular passage, then the tuner will reveal whether or not you are able to play that note 10 cents sharp every time you play that passage.

Final thoughts

Intonation is such a vast topic-far more so than many people think. A discussion of this size can only serve as a summary or an overview. In addition to the ideas listed above, certain other items deserve mention:

- If you can't sing any given pitch (at least in some octave), you can't expect to be able to play it in tune. You must always be able to imagine the pitch before you play it, in order for your ear to be able to evaluate the pitch and guide your efforts.
- Intonation work is so much easier if your tone is good. A satisfactory tone is a prerequisite for intonation work.
- Intonation can be a device for musical expression. Once you can play a passage such that every note sounds in tune, any further refinements of the tuning will affect the "color" or the mood of the pitches, and as such can be used to affect the aesthetic of the music.
- If you find yourself needing to adjust a pitch, it is important that you adjust it only in a single direction. "Fishing for pitches," should be strictly avoided!

- Speed also plays a factor in intonation. Rapid pitch changes require more exaggerated differences between intervals and interval categories. Faster pitch changes also tend to require more melodic, as opposed to harmonic, tuning.

Improving your intonation is a lifelong process and a fascinating challenge. No one is ever so good at intonation that he could not benefit from further study of the topic. Players of fixed-pitch instruments don't know what they're missing!

Bibliography:

Ballard, Dana and Cornelia Yarbrough. "The Effect Of Accidentals, Scale Degrees, Direction, And Performer Opinions On Intonation," *Update: Applications of research in music education* 8 (1990): 19-22.

Balzano, Gerald J. "Musical vs. Psychoacoustical Variables and their Influence on the Perception of Musical Intervals." *Bulletin of the Council for Research in Music Education* 70 (1982): 1-11.

Barbieri, Patrizio. "Violin Intonation: A Historical Survey," *Early music*, 19 (1991): 69-88.

Barbour, J. Murray. *Tuning and Temperament*, 2nd ed. New York: Da Capo Press, 1972.

Benade, Arthur H. *Fundamentals of Musical Acoustics*, 2nd ed., rev. New York: Dover Publications, 1990.

Boer, E. de, "Pitch Theories Unified." *Psychophysics and Physiology of Hearing* ed. E. F. Evans and J. P. Wilson, 323-334. London: Academic Press, 1977.

Boomsliter, Paul, and Warren Creel. "Extended Reference: An Unrecognized Dynamic in Melody." *Journal of Music Theory* 7 (1963), 2-22.

Boomsliter, Paul, and Warren Creel. "The Long Pattern Hypothesis in Harmony and Hearing." *Journal of Music Theory* 5 (1961): 2-31.

Bregman, Albert S. Auditory Scene Analysis: The Perceptual Organization of Sound. Cambridge, MA: MIT Press, 1990.

Brown, Rebekah Ann. "Dynamics Of Intonation In Performances By Artist Violinists." Ph.D. diss., Indiana University, 1996.

Burns, Edward M. "Intervals, Scales, and Tuning." *The Psychology of Music*, 2nd ed., ed. Diana Deutsch, 215-64. New York: Academic Press, 1999.

Butler, David. *The Musician's Guide to Perception and Cognition*. New York: Schirmer Books, 1992.

Deutsch, Diana. "The Processing of Pitch Combinations." *The Psychology of Music*, 2nd ed., ed. Diana Deutsch, 349-411. New York: Academic Press, 1999.

Elliot, J., J. R. Platt, and R. J. Racine. "Adjustment of Successive and Simultaneous Intervals by Musically Experienced and Inexperienced Subjects." *Perception & Psychophysics* 42 (1987): 594-598.

Fyk, Janina. "Static And Dynamic Model Of Musical Intonation." SMAC 93: Proceedings of the Stockholm Music Acoustics Conference, July 28-August 1, 1993. Stockholm: Kungliga Musikaliska Akademien, 1994, 89-95.

Fyk, Janina. Melodic intonation, psychoacoustics, and the violin. Trans. Joanna Ciecierska. Zielona Gora: Organon, 1995.

Garman, Barry Rex. "The Effects Of Accompaniment Texture And Contextual Pitch Distance On String Instrumentalists' Intonational Performance." Ph.D. diss., University of Miami, 1992.

Gelfand, Stanley. *Hearing: An Introduction to Psychological and Physiological Acoustics*. New York: Marcel Dekker, 1990.

Genevro, J. Bradley. "Ways To Improve Intonation," Teaching Music 4 (1997): 30-32.

Geringer, John M. "Comparison Of Good Versus Bad Tone Quality/Intonation of Vocal and String Performances: Issues Concerning Measurement and Reliability of the Continuous Response Digital Interface," Bulletin of the Council for Research in Music Education no.141 (Summer 1999): 86-92.

Geringer, John M.; Madsen, Clifford K. "Musicians' Ratings Of Good Versus Bad Vocal And String Performances," *Journal of Research in Music Education* 46 (1998): 522-534.

Goldstein, Julius L. "An Optimum Processor Theory for the Central Formation of the Pitch of Complex Tones." *The Journal of the Acoustical Society of America* 54 (1973), 1496-1516.

Greene, Paul C. "Violin Performance with Reference to Tempered, Natural, and Pythagorean Intonation." University of Iowa: *Studies in the Psychology of Music*, vol. 4, 232-251. Iowa City: Iowa University Press, 1937.

Hajdu, Georg. "Low Energy and Equal Spacing; the Multifactorial Evolution of Tuning Systems." *Interface* 22 (1993): 319-333.

Benjamin Whitcomb, associate professor of cello and music theory at UW-Whitewater, is a graduate of UT-Austin and Oklahoma State University. Whitcomb has produced several CDs of his recordings, including a collection of works for unaccompanied cello with MSR Classics. He is a contributing author to *Teaching Music through Performance in Orchestra*, Vol. 3, and is currently helping to revise the cello portion of the *ASTA String Syllabus*. He is past president of the Wisconsin Chapter of ASTA. He has presented numerous papers on cello and on music theory at national conferences, including those of ASTA and the Society for Music Theory. He is also an articles editor, a book reviewer, and the editor of the Cello Forum of the *American String Teacher* journal. He is a frequent guest clinician and performer at high schools and summer camps, including the National String Workshop and universities throughout the country. An expert in the area of string pedagogy, Whitcomb is known for his work in teaching both technique and musicianship. He recently finished writing a book on practicing the cello, which is scheduled to be available in the spring of 2008. Whitcomb was chair of the instrumental faculty at the La Musica Lirica music festival in Nova Feltria, Italy, from 2004 to 2006. He has been recognized by the UW-W music department for his outstanding teaching and research. For more information, visit Whitcomb's website at www.benjaminwhitcomb.com.