The paradox of musical acoustics: Objectivzing the essentially subjective

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Music Acoustics. The study of music acoustics may be considered the quintessential interdisciplinary musical science, requiring expertise in a number of areas, including but not limited to musical performance, psychoacoustics, and physics.

Background in acoustics. Acoustics is the science that deals with the production, control, transmission, reception, and effects of sound. Sub disciplines include speech processing, room acoustics, environmental noise, vibration in vehicles, ground vibration, marine mammal communication, bioacoustics and musical acoustics. Sub disciplines of musical acoustics include music perception, physical modeling, music performance, and instrumental acoustics. One of the goals of instrumental acoustics is to define quality parameters enabling objective judgments of musical instruments. These quality parameters are largely dependent on subjective factors, however, and remain elusive.

Background in music performance. Musical instruments evolved by trial-and-error, fulfilling developing needs of contemporary musicians. Instruments and musicians' playing techniques developed a high level of sophistication long before they came under scientific scrutiny in the last century. Skilled musicians may be able to say immediately if they like an instrument without any idea of its physical function based on his or her traditions, habits, taste, and expressive vision. The complex and ethereal judgement factors of musicians make it therefore difficult to obtain unified quality judgements to correlate with objectively measurable acoustical data.

Aims. The authors submitted this paper to ensure the presence of musical acoustics at this excellent and important conference. It is of great importance to share knowledge among researchers in perception, performance, and other types of musicology to enable further advances in all of our fields.

Main contribution. The main point of this talk is to introduce the interdisciplinary field of musical acoustics, characterize difficulties of scientifically objectivizing the essentially subjective and mysterious entity of music, and to present some approaches that have been used to define quality parameters of musical instruments. While great advances in the understanding of physical aspects of musical instruments have been made, science will be perpetually dependent on the judgments of musicians and listeners to give their findings relevance in a musical context. The writings of some of the "parents" of modern musical acoustics will be taken into account in the discussion of how science and music performance can be combined.

Implications. One possible reason for the difficulty of quality judgement is that music acousticians are confronted by a great paradox: in isolating the musical instrument from the musician, the room environment, and the listeners, the scientist removes the subjective factors involved. These subjective factors are, however, precisely those intimately connected with the main purpose of musical activity: expression.

If one isolates a musical instrument as a physical, measurable object, one can find out much about its intrinsic qualities, like resonant frequencies, radiation directivity, etc., and how the object functions. But to analyze the instrument, a music acoustics researcher must remove several elements from a crucial musical equation. What is here called the “musical equation” is the chain of sound source (musician/instrument), transmission medium (air/room) and receiver (listener). It is obvious that a substantial part of the musical experience is directly connected to who and what is playing, where they are playing, and who is listening. No clarinet plays itself. Of course, if it could, as we’ve seen from experiences with automatons or electronic music performances, would the expressive content of the performance say something meaningful to live listeners? It is argued here that music is essentially an expressive activity, requiring not only someone actively saying something, but also someone actively listening to it and interpreting it. Thus the task of making quality judgments independent of the musical context is tricky indeed.

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Musical (Music) Acoustics

Acoustics is the science that deals with the production, control, transmission, reception, and effects of sound. Sub-disciplines of acoustics include speech processing, room acoustics, environmental noise, vibration in vehicles, ground vibration, marine mammal communication, bioacoustics and musical acoustics. Sub-disciplines of musical acoustics include physical modeling, music performance, music perception and instrument acoustics. Applications of instrument acoustics include using knowledge to support musicians in performance practice, to help instrument makers make design changes on existing instruments to achieve specific goals or to make new instruments, to design cheaper and better instruments, to find replacement materials for increasingly rare natural materials, etc.

There has been some discussion as to whether our field should be called “music acoustics”, rather than “musical acoustics”, since the word “musical” connotes something having to do with peoples’ talent or skill as musicians and thus, in the opinion of Johan Sundberg, inappropriately named (Sundberg, 1989, 4). Both names appear here interchangeably.

Instrumental acoustics researchers may be basically divided into groups of theoreticians or empiricists. Most instrumental research uses theoretical modelling and simulation to explain the details of the physical function of instruments. Other theoreticians are not interested in simulating the function of an instrument, but in making realistic imitations of existing instrument sounds or creating new sounds for commercial synthesizers or computer music.

The second group instrumental acousticians, to which the author and co-author belong, uses empirical observations on instruments within a more or less practical musical context to help instrument makers and musicians to solve specific problems. To get at measurable quantities that are significant for the musician’s subjective judgment of an instrument’s quality is a big challenge, for it requires a good deal of knowledge and skill spanning different disciplines. This is why interdisciplinary teams are so important to music acoustical research. The research team at the Institut für Wiener Klangstil, part of the University of Music and Performing Arts in Vienna, consists of practicing professional musicians, systematic-comparative musicologists, an electro-technical engineer, physicists, computer programmers, and a technician to build audio and measurement equipment. This interdisciplinary conglomeration of specialists is beneficial, and indeed necessary, to tackle the complex problems that research at IWK poses.

As stated, research approaches in the second area are based on empirical observations of structured experiments and, importantly, surveys of musicians and listeners. From this perspective, it is clear that musical instruments have intrinsic qualities of their own, which can be measured by a variety of means, but that these qualities are only significant in the context of a musician’s ability and desire to express him- or herself with the instrument in question. No doubt, both areas are crucial to the understanding of musical acoustics, on the one hand for understanding the physical function of musical instruments, but on the other hand for finding the significance of these details in the musical, expressive context. A comparison may be made with other advances in technology, for example, the development of a new, inefficient luxury vehicle. The natural sciences provide the ‘how’ by numerically describing what it takes to make one that works, with all its features, but philosophical reasoning is required to come up with the ‘why’ or ‘whether’ as to actually driving it, to the likely demise of the environment.

Words of some music acoustics pioneers

For helping to define musical acoustics, and for guidance on the path between the scientific and artistic, one can look to the writings some of the pathfinders in this field.

In *The Fundamentals of Musical Acoustics*, Arthur Benade describes musical acoustics as "the meeting place of music, vibration physics, auditory science and craftsmanship" (Benade, 1976, 3). Donald Hall writes in *Musical Acoustics*, "In musical acoustics we have a unique opportunity to see science and art working together. Along the way they are sometimes friendly antagonists, but ultimately they are partners in teaching us what music is and how it works." (Hall, 1990, vii).

The introduction to Neville Fletcher and Thomas Rossing's important book *The Physics of Musical Instruments* contains many useful words to guide on the path between the objective and subjective. They write, "The first and major role of [musical] acoustics is… to try to understand all the details of sound production by traditional instruments. This is a really major program." It's also a program that has come far since the seminal treatise *On the Sensation of Tone* by Hermann von Helmholtz published in 1863, but that has much work left to be done.

Further, they write, "The history of musical instruments is nearly as old as the history of civilization itself, and the aesthetic principles upon which judgments of musical quality are based are intimately connected with the whole culture within which the instruments have evolved. An educated modern Western player or listener can make critical judgments about particular instruments or particular performances but, to be valid, those judgments must be made within the appropriate cultural context."

"There is no such thing as an 'ideal' instrument, even in concept… Thus, for example, the sound and response of a violin are judged against a mental image of a perfect violin built up from experience of violins playing music written for them over the centuries. A new instrument may be richer in sound quality and superior in responsiveness but if it does not fit that image, then it is not a better violin."

Fletcher and Rossing proceed, "Our understanding of a particular area will be reasonably complete only when we know the physical causes of the difference between a fine instrument and one judged to be of mediocre quality. Only then may we hope that science can come to the help of music in moving the design of performance of contemporary instruments closer to the present ideal."

"It is difficult…for a scientist to point the way forward unless the problem of the opportunity has been identified adequately by the performer or the maker" (Fletcher and Rossing, 1998, vii-viii). The 'identified problem' is the **target function**, which is the key for finding the solution to specific problems that detract from an instrument's quality.

Murray Campbell and Clive Greated describe an imaginary concert situation on page one of their book *A Musician's Guide to Acoustics*: the audience, orchestra, and soloist settle down to a performance of Beethoven's Piano Concerto Nr. 5. Also present is an extraterrestrial alien observing the scene, immune to 'the magic spell we call music'. While the unemotional alien's observation is limited to seeing humans "scraping horsehair over metal wires attached to wooden boxes of various sizes", etc., "he has, of course, missed the point. Underlying the somewhat fanciful talk of 'magic spells' is the truth that the communication of a *human experience* is at the heart of the music. An observer who is incapable of sharing the experience is liable to be led seriously astray in any attempt to investigate the processes involved in playing or listening to music. Occasionally some earthbound scientists have fallen into this trap." (Campbell and Greated, 1987, 3-7). So, it is essential to be mindful of the musical context while observing 'metal strings attached to wooden boxes'. When confronted with the question as whether the 'average' orchestral musician needs detailed musical acoustics knowledge, Campbell and Greated are firmly convinced that "it is possible to steer a middle course between the bog of incomprehensible technicalities and the slippery slope of unsupported generalities."

Case Studies

In our discussion of musical acoustics, its character as an interdisciplinary science, and the paradoxical wedding of the objective and subjective, we would now like to present a few case studies to illustrate approaches to the problem. Earlier studies on violins, a recent study on the double bass, and a current study on trumpet response are described.

Deduction of quality parameters of violins

Dünnwald and Jansson used expensive instruments as their point of reference in their studies to find the most important quality parameters of violins. The approach works backwards from the generally accepted idea that old and valuable Italian violins the best, and the hypothesis was that the input admittance curves of violins generally recognized to be good share quantitative characteristics that set them apart from 'bad' violins. Dünnwald grouped violins by origin, age, price class, maker and by who played on them, and the input admittance of over 700 instruments was measured. The subsequent analysis of the resulting curves showed quantitative tendencies common to most old, Italian instruments (Dünnwald, 1988).

Jannson made a similar deduction in his study, and correlated his data from these prestigious instruments with the findings of other leaders in violin research. (Jansson, 1995). The approach is indeed convincing if it is true that old Italian violins are better. In support of the claim of better quality are the financial value and prestige of such instruments, and not the least, the consideration of the 'famous musicians' whose violins Dünnwald counted as more important than of unknown violinmakers.

Acoustical comparison of flat- and round backed double basses

The goal of the author's recent study was to determine whether there are significant measurable, acoustical differences between double basses of two different form types, namely with a flat back or round back, and to determine if these measurable differences are audibly significant. While the first question necessarily leaves humans out of the experimental process, the second depends completely on live listeners and their decisions.

Since the physical structure of the two types of bass are quite different, it was to be expected that one would find lots of well-defined, measurable differences between the test instruments differing only in the form of the back, which was indeed the case. It was, however, unclear whether the contrasting vibration responses would cause a difference in the radiated sound that would be important or even noticeable for musicians, since the characteristic frequency range of the double bass, between 300-500 Hz (Meyer, 1995, 222) is below the ear's best sensitivity (Roederer, 1975, 97).

The first step of the research was to conduct a survey of bassists and instrument makers to determine contemporary trends in usage and preferences of the two types. Preferences were highly individual, though the majority prefers to play or make round backed basses not only for sound, but also because of structural stability advantages of that type. After the acoustical measurements and analyses were performed, a listening test was performed using two instruments, identical except for the back plates, with a live player shielded from a live audience by a screen. During the test, members of the audience were asked to identify the flat backed or round backed bass in 28 paired test tones, based on their expectation of the sound. Two bassists identified the basses correctly most often because of previous experience. Recordings from the live listening test were used for a recorded test in which 53 participants matched the first or second tone with a third, thus defining the audibility of differences between the two bass types. Synthesized tones were also used based on the averaged FFT spectrum of live-recorded tones, which represented the timbre of the bass type while minimizing the effect of the player's transients that strongly affect timbre. The most difficult tones to match correctly were the real tones recorded in the far field, showing that while there is an audible difference between the two types, the player and the room acoustics can cause more difference in timbre than the form of the back plates.

This approach did not pose the question as to which type sounds better to an individual or group of listeners. But since there is an audible difference attributable to the back type, the preferences of bassists and instrument makers outlined by the preliminary surveys may be rooted in the artistic fulfillment players achieve with one back type or other.

Trumpet studies

Musicians' impressions are permanently changing in time, which poses one of the possibly unsolvable difficulties of qualitative judgments based on live musicians' decisions. We argue that each listening or playing experience is unique in time and subject to a myriad of parameters that are extremely complex, thus making it difficult to discover by this means the intrinsic qualities that make an instrument 'good'.

The co-author's current study on trumpet response is a detailed examination of subjective quality parameters. The approach narrows trumpet response-related parameters of trumpets into specific categories, which are then rated in blind tests by musicians playing five test instruments. The parameters include aspects such as timbre quality, ease of playing pianissimo, etc. Each of these parameters is rated on a scale of 5 from –2, -1, 0, 1, or 2, with negative values being judged to be bad, 0 being a neutral reaction, and 2 being good. Looking at these isolated parameters, which are the puzzle pieces of the musician's momentary impression of the entire instrument, in a systematic way gives clues about the quality judgments of one or more players about the trumpet and its response.

But how consistent are these impressions? Will a musician rate the parameters of a trumpet in the same way if he or she has an important appointment afterwards, has a headache, or is tired from drinking all night. To test this, the same musicians are sometimes given the same trumpets repeatedly, but are told that each trumpet is a new trumpet. In the test situation, the room is darkened, the researcher hands the test participant a 'new' trumpet for each survey, which has been altered in some detail (leadpipe, valve section, etc.). The researcher conducts an interview while the instrument is tested, recording the ratings of parameters. The tests are designed to result in a large number of judgments, hopefully resulting in statistically significant data, first of all, about the *repeatability* of player's judgments of the same parameters, and finally about the objective qualities of the parameters themselves. If player's judgments of the set of parameters are indeed consistent over several test runs under varying conditions, then these qualitative judgments may indeed be getting closer to what a musician likes (individual target function) or *most* musicians like (target function tailored to the statistical majority) about the way a trumpet responds.

Subsequently, the measurable aspects of the trumpets that were positively or negatively judged may then be measured with numerical means, such as with BIAS, the input impedance-measuring device developed at IWK. Correlation of the judgments of players, should they be consistent, should result in the connection of even more measurable quantities to subjective quality judgments of one or a population of musicians.

Summary

The discipline of musical acoustics offers many possibilities, but sometimes unanswerable questions are asked of it. On one hand, researchers have learned a great deal about the function of musical instruments, though there is still much work to be done. But because instruments are tools with which musicians and audiences express themselves within a musical context, the ideal instrument for all musicians will never be found. While it's impossible to absolutely classify instruments as bad or good on a purely objective basis, it is possible to discover the ideal instrument for an individual by defining his or her target function. It is also possible to find a target function of a statistical majority to match the needs of 'most' users. Music acoustics will always be essentially interdisciplinary to better understand both the 'how' and the 'why' and 'whether' of music-making.

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