Musical Acoustics, the Music Student and the Music Teacher

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ABSTRACT

Dialogs between musicians and acousticians are not always successful. Lack of common language combined with mutual suspicion of the other person trespassing one's own professional authority, often restricts what ought to have been a fruitful exchange of knowledge. For the music student, there is however a third matter that seriously impedes the possibility of gaining acoustical insight. As for all arts, yearning and intuition are the driving forces in the development of musical and instrumental skills. Focus on purely technical matters, or even worse, the feeling of being overruled by such, is hardly combinable with a desirable musical progress of the young student. Based on the author's experience as a principal professional player and teacher of music for more than thirty years, this paper gives some suggestions on which and how topics in musical acoustics may be introduced.

CAN A PIANIST ALTER THE TONE COLOR IN HIS INSTRUMENT?

If you, as an acoustician, were asked: "*Can a pianist alter the tone color in his instrument without altering the loudness?*" What would your answer be? The question is a tricky one, and any answer except "yes" would be rejected by most pianists. The "touch" of great pianists is a highly regarded feature in their playing, and is often the first characteristic that makes it possible for the advanced listener to distinguish one player from another after having heard only a few bars. On the other hand: at the moment a piano hammer leaves the lever, thus disconnecting from its key, it leaves with a given velocity that seems to be determining both the timbre and the loudness. The felt hammer has a velocity-dependent compliance that causes it to produce more overtones when hitting the string hard. Vibrations in the hammer shaft have been reported[1], but not of a magnitude that likely could serve a pianist trying to alter the timbre. Seashore[2] pointed at this paradox already in 1938, but the issue remains largely unresolved.

First, the musician may have a different understanding of the words *timbre* and *tone color* than the acoustician. Askenfelt[1] has shown that the percussive "thump" of the piano key hitting the stop rail of the key frame can be quite prominent in the sound of the attack. This thump can however to some degree be controlled independently of the hammer velocity mentioned above. The timing of depressing the pedal also influences the attack and makes it possible to accentuate the tone onset without changing the loudness of the subsequent sound. (This sequence is: key down-key up-pedal down, where the last interval determines the degree of onset damping.) The dynamic effects of *sforzato* (***sfz***) and *fortepiano* (***fp***) may be achieved this way, with the spectral consequence that the high-frequency content, after the pedal has been pressed down, is increased in comparison to a normal note.

Timing between individual notes is another topic. Galembo[3] has shown that in runs, single notes on the piano are often heard only as superimposed on the preceding one. That is, they are not *perceived* as such, but analyses show that some of these never play alone. This effect may partly have to do with the damping mechanics of the piano, but is also at hand for the player to use if properly skilled. When playing chords, changing the tone color is somewhat easier, even when maintaining the dynamic level of each individual note: the pianist knows that by attacking the highest notes slightly earlier than those of lower pitches, the chord will sound harder and more piercing, and vice versa. Although probably being the most substantial part, the final hammer velocity constitutes only one of several aspects in producing the complex picture perceived by the player as "timbre".

In short, a statement like: "*A pianist cannot alter the tone color in his instrument without altering the loudness*" is not necessarily the most helpful answer to a student who is working on his "touch".

WHAT IS HELPFUL INFORMATION?

Tone onset is indeed an interesting topic for most instrumentalists, and a matter in which they invest a substantial amount of their practice time. More research on the transiental behaviour of the different instruments would be warmly welcomed, provided it can be expressed in relatively unsophisticated terminology. Some years ago, a study (I have unfortunately forgotten who wrote it) showed through use of electromyographic equipment that trombone students in average prepared their embouchure (mouth-and-lip condition) later than their tutors when preparing for an attack. This anticipation was particularly important for attacks in the highest register of the instrument, where the students failed more often than their teachers. Such empirical information, combined with some knowledge on how their lips take part in the resonating system, provides accessible easy-to-understand pictures of the acoustical situation they are trying to master.

The music teachers are usually utilizing a series of fancy images in describing the different phenomena of their instruments and the ambient acoustics: "*If you slacken the hair of your bow, it will touch more of the string's surface. That way you'll increase the friction.*"... "*Low frequencies travel more slowly than the higher ones. That's why double basses always sound late in the concert hall.*" I presume statements like these two sound silly to an acoustician, but they may actually contain some insight, although the wording is definitely not right.

Let us use the late-sounding double basses as our example here: the acoustician knows that given a "switched-on" input signal of constant amplitude, a resonant instrument will respond with an exponentially growing output until the losses equal the input power. This exponent is for a large part a function of the frequency. No matter how much the bassist tries, he can never really compete with the quickly-building transients of the violin, as long as their playing frequencies are so different. But: even the violin comes second to most high-pitched wind instruments in this respect, because its input signal, i.e., the string, is far from making a switched-on transient. The buildup of the string signal is by itself exponential at the best[4], and requires considerably more time than the response of the instrument body alone. (In a string transient, the dissipation is more or less constant from the onset, partly due to the negative resistance of the rosin.) If all the members of a symphony orchestra attack a chord at the very same instant, there is no doubt that the hall will be filled with high-frequency energy first, followed by a gradual buildup of energy in lower frequency range. Although the audience is used to hearing this, it is not necessarily the ideal situation, musically.

Is there anything the string players can do? There is! They can be aware of which rules apply when trying to start a note quickly: for any given bow force (-"bow pressure" or -"bow weight" as music teachers pedagogically prefer to term it), there is a narrow range of accelerations that will produce triggering of the Helmholtz motion from the first cycles[5]. With occasional exceptions, this is what the string player wants to achieve[6]. Unfortunately, *acceleration* does not tell very much (can *you* picture what an acceleration of, say, 250 cm/s^2 looks like?). *Speed* is easier to grasp. The way for the acoustically informed music teacher to address the problem is, however, to refer to the tightness of the bow "grip" or bow "hold" (where the latter is the pedagogically preferred word). By holding the bow more tightly, more mass is added to it, and a smoother acceleration assured. Furthermore, by tautening the joints of the arm, the acceleration can be kept low whenever this be desirable. The player is then preventing the bow from *moving too fast* for the given bow "weight". To match the onset transient of more quickly responding instruments, the string player should practise a variety of attacks in order to find the acceleration limits for the given note. Normally a more rigid grip is required when playing close to the bridge and on low strings. It is only when the term *acceleration* has been connected to something perceivable and to a particular *sound quality* that it will serve as useful information for a less-technically-inclined string player.

INTONATION

Intonation represents an eternal struggle for wind and string players alike. Many problems have basis in the difference between homophonic and melodic intonation. In addition comes our desire to stretch octaves. Perceptional acoustics should find its way into the music academies much more often than it does today. Some instruments have, however, intrinsic intonation flaws, and the musician must learn to cope with them. In a recent doctoral thesis, the musician and acoustician Leonard Fuks[7] discusses the influence of carbon dioxide (CO_2) content on pitch in wind instruments. While the influence of ambient air temperature on pitch is common knowledge (a raise in room temperature from 20 °C to 25 °C may cause a raise in pitch of about 17 cents), the unavoidable increase in the respiratory CO_2 level between each inhalation has not earlier been given the same attention. Fuks shows that in long oboe phrases, this level may vary between some 2.5 and 8.5 percent, and potentially cause a frequency shift of about -20 cent (i.e., more than 1%). Such information is absolutely of interest to the player. The musician (mostly!) makes up for this pitch drift without knowing it. However, care *could* be taken so as to avoid starting with "old air" if some notes of a certain phrase tend to sound flat on the instrument. On the oboe and some other winds, circular breathing (inhaling through the nose while maintaining the mouth-cavity air pressure) may remedy the problem simply by permitting more frequent inhalation, thus keeping the CO_2 levels more restricted.

THE DIALOG BETWEEN THE ACOUSTICIAN AND THE MUSICIAN

It is my experience that a majority of the musicians and music students have very vague concepts about many basic acoustical terms, such as for instance "overtones" or "partials" - how they sound and what they are. The CD "Auditory Demonstrations"[8] gives excellent examples of overtones and many other important phenomena, which in one form or another should be incorporated in the ear-training courses of our music academies. On the other hand, the music student/musician may feel quite sceptical about any *musical idea* offered by acousticians or other "nonprofessionals". I remember well my own annoyance when I years back read the following statement in Seashore's *Psychology of Music*:

"However, an ideal vibrato which can be gradually developed through musical criticism and musical education will probably be smooth in variations of rate and extent, will have a cycle which approaches the perfect sine curve, will probably be one cycle per second faster than the present, will have a higher artistic variability, will be adapted to solo and ensemble performances, will have a pitch extent of approximately one-half of the present average for voice, and will probably be present in all tones and transitions except where the nonvibrato is used for specific effects." My margin comment read: Mind your own business!

The musician very often pictures tones as movements of objects of different masses and colours when playing. Here we might be approaching the core of the communication difficulty between acousticians and musicians: whereas the acoustician needs to split a phenomenon into a set of separable parameters, the musician needs to picture it as an entity in order to be juggling with it. Considering the physical and physiological complexity of playing an instrument, whatever parameter separation done during the practice of basic technique, one must be sure to have it all recombined long before the stage is entered. The pianist cannot think: "*Since the string spectrum cannot be changed when maintaining this particular dynamic level, I'll try to add a little stochastic noise to the sound.*"

[1] A. Askenfelt and E. Jansson. "From touch to string vibrations". (pp 39-57 of "*Five lectures on the acoustics of the piano*", A. Askenfelt ed.) The Royal Swedish Academy of Music, Stockholm 1990.

[2] C. M. Seashore "Psychology of Music" 1938.

[3] A. Galembo, "Sounds overlapping in melody played on a piano" Proc. of the 15th Int. Congress on Acoustics (ICA'95), Trondheim, Norway pp- 26-30 June 1995.

[4] J. C. Schelleng, "Pressure on the Bowed String", CAS Newsletter #13, May 1970 pp 24-30.

[5] K. Guettler, "Bow notes"Proc. of ISMA'97 Vol.19: Part 5 (1997), Book 1: pp 1-10.

[6] K. Guettler and A. Askenfelt, "Acceptance limits for the duration of pre-Helmholtz transients in bowed string attacks" J. Acoust. Soc. Am. 101 (5), Pt. 1, May 1997, pp 2903-2913.

[7] L. Fuks, "From Air to Music, Acoustical, Physiological and Perceptual Aspects of Reed Wind Instrument Playing and Vocal-Ventricular Fold Phonation." Thesis for PhD. Royal Institute of Technology, Dept. of Speech, Music and Hearing (1998) ISSN 1104-5787.

[8] Auditory Demonstrations, IPO, NIU, ASA, 1989. (CD, Philips 1126-061)