1. A small loudspeaker system, developed by Graham Caldersmith, consisting of a small loudspeaker driving the violin plate via a small wood pyramid. This system works well to excite the free plates. It causes only small perturbations of recorded resonance frequencies. The system contains within itself some resonances, causing a "hill" in the range 2 to 6kHz. The center-frequency of this hill depends strongly on the applied static force.

2. The driving system used by Carleen Hutchins, a fixed magnet and a moving electrical coil fastened with sealing wax to the violin plate. It is also a good system to set the plates in vibration, but we had a problem with the Q-values. They were not easy to reproduce and were unexpectedly low.

3. The "impedance head" that was developed at the Royal Institute of Technology in Stockholm, consisting of a fixed electrical coil working on a movable small magnet fastened to a small accelerometer, which in its turn is fastened to the plate[3]. This system works well to excite the plate vibrations, and gives only small mass perturbations. It is easy to work with and gives high reproducibility.

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On recognizing violins: starting transients and the precedence effect.

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SUMMARY

A possible relation between discrimination of certain starting transients on violins and the perception of sound in reverberant rooms is explored in an informal manner. If true, the idea has significant consequences for future research into the principles of violin construction.

INTRODUCTION

As the non-playing member of a violin acoustics partnership, I have over the past few years spent quite some time listening to violins being played. In particular, I am practised although not very gifted at blindfold listening tests for differences between instruments. One particular aspect of that experience has puzzled me for some time, and I present here the germ of an idea which helps to explain it. I hope others might be sparked to develop the idea, or perhaps to do the systematic psychoacoustical experiment needed to test the idea in detail - the latter at least I am not equipped to do.

First, to describe the experience. Two violins are being played alternately by a competent player, and while you are watching it seems that you can hear all manner of differences between them quite clearly. The blindfold goes on, and for most people panic sets in as all differences seem to vanish entirely. After a while a measure of discrimination returns, when at least a certain class of clear differences between instruments can be discerned reliably, even by those whose ears are no more sensitive than mine. One way in which this happens is that you learn to trust your initial impression on hearing the first note played on a given instrument, especially if played with a martelé or similar abrupt starting transient. Hearing further notes on the same instrument may tend simply to sow doubts in the mind that your identification is correct.

The really interesting thing is that once one has identified an audible 'quality' distinguishing the two instruments in such starting transients, one hears essentially the same quality distinction whichever note is played, at least within the low-to-middle range of the instrument's compass. (High E string notes tend to sound rather similar on most instruments at the rather crude level of distinction we are discussing here, with no musical content or context to aid discrimination).

Thus some characteristic signature of an instrument can be conveyed to the listener from a single martelé starting transient of any low or mid-range note. It is immediately clear that the clue must lie in the transient, since the steady-state spectrum of the note cannot possibly convey any such signature independent of the note played - a moment's thought about violin frequency response curves tells us that. So here is the puzzle: what kind of easily-heard signature could emerge from a complicated starting transient played on an instrument with a complicated frequency response, independent of the note played?

My suggested answer is that there is a significant resemblance between the character of the sound reaching the listener's ears from a martelé starting transient on a bowed-string instrument and that from a sound source in a room. New we have a sophisticated processing ability for coping with echoes in rooms, centering around the precedence effect[1], and I suggest that this same ability is thus available for analyzing violin starting transients in a particular way to give a clearer perception than at first sight seems possible. It will turn out that the proposed mechanism fits in rather well with the symptoms described above. To understand this suggestion, we need to recall a little about bowed-string transients and a little about the precedence effect.

THE PRECEDENCE EFFECT

When a sound - a hand-clap say - is made in a room, the first thing to reach the listener's ears is sound by the direct path. After that first arrival, with time-lags depending on the geometry of the room, follow echoes of the clap which have reflected one or more times from the walls, floor, ceiling and furniture of the room. The first few echoes will be well separated in time. As time goes on, however, the density of arrivals increases while the individual echoes get fainter, so that separate arrivals merge into a reverberant 'mush' of sound.

Our brains recognize the early arrivals, provided they come within 50mS or so of the direct sound and provided they are not regularly spaced, as being not new sounds but more copies of the original direct sound. This means that instead of the echoes making it harder to hear details in the sound, they can actually make it easier since the brain has several copies of the original sound to work on. This is the precedence effect. It has been discussed at some length in a musical acoustics context by Benade[2]. This effect is the reason that most people would prefer to hear a string quartet, say, playing in a suitable room than in the open air, even if the only consideration were clarity of perception of details in the sound.

BOWED STRING TRANSIENTS

During a steady note the motion of a bowed string is the well-known Helmholtz motion[3], in which a 'corner' shuttles back and forth along the string triggering transients between sticking and slipping as it passes the bow. To a good approximation the string motion communicates with the body of the violin and thus eventually with the ears of the listener only through the bridge. Thus the aspect of string motion we should concentrate on is the waveform of force exerted by the string on the bridge. For a Helmholtz motion this waveform is a sawtooth, with a rapid flyback as the Helmholtz corner reflects from the bridge. An example, from steady bowing of an open violin G string, is shown in Fig. 1.

Our interest here is not in steady notes but in starting transients. The bridge-force waveform of a martelé transient played on the same open G string as Fig. 1 is shown in Fig.2. The time scale is the same in both figures. Periodic Helmholtz motion is more or less established by the right-hand side of the picture. The force waveform consists essentially of a collection of flybacks, each one similar to the Helmholtz flyback, but irregularly spaced over a total time of some 50mS. These then settle into the regular pattern of the Helmholtz motion.

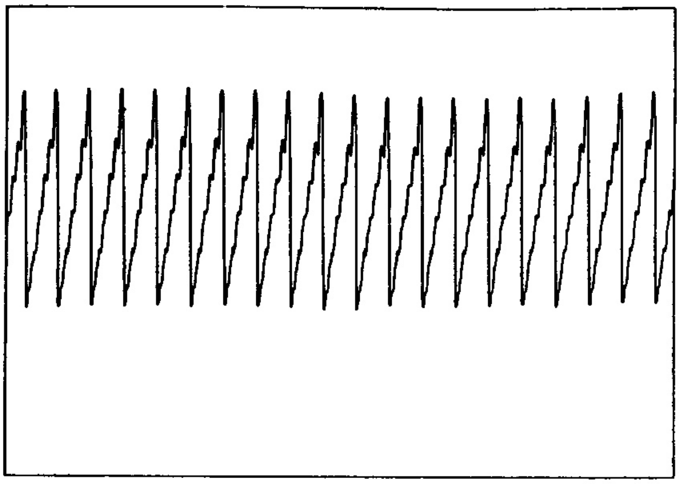

Figure 1

Bridge-force waveform during steady bowing of an open violin G string. The total time range shown is 102mS.

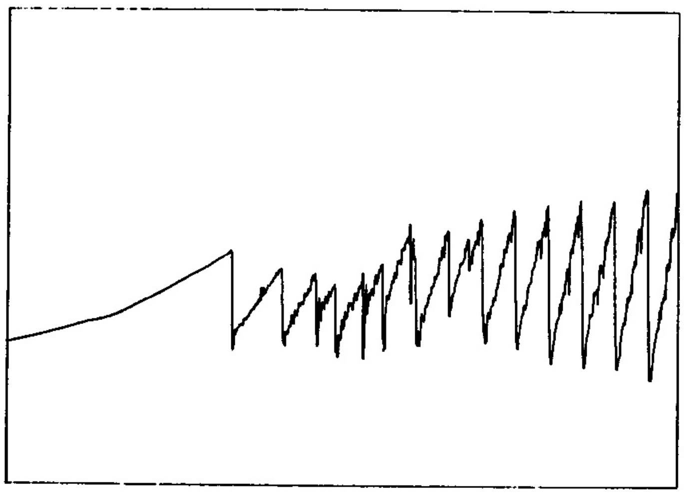

Figure 2

Bridge-force waveform during a martelé starting transient on the same open violin G string as in Fig. 1. Again, the total time range shown is 102mS.

We now consider what kind of response will be elicited from the violin body by a bridge-force waveform like that of Fig. 2. The body response to a single flyback is a characteristic 'clonk', as the various vibration modes of the body are excited and ring on with their individual frequencies and damping factors. Roughly the same sound is produced by flicking the corner of the bridge in its own plane with the back of the fingernail (with the strings damped). A more accurate rendering of the sound can be produced easily with the bow, by pressing so hard and bowing so slowly that individual releases of the string from the bow are heard.

Now as the martelé is played, each of the flybacks in Fig. 2 produces a separate copy of this 'clonk' noise. The resulting sound from the violin consists of an irregularly-spaced series of essentially identical clonks occupying in total some 50mS. This description closely mirrors that of the sound in a room following a hand-clap given above. Thus we can expect the precedence effect to swing into action and give us surprisingly good discrimination of details in that clonk, even if we do not think of it in that way as it merges into a periodic note quite different from the reverberant tail of room response.

but walls are only a foot or two away.

THE CONNECTION, AND THE CONSQUENCES

Here, surely, we have an explanation of the original observation. Naturally, the clonk does not depend on which note is played on the violin - from our present point of view the eventual periodic note is just a distraction from hearing the clonk more clearly! Equally obviously, the clonk is certainly a characteristic signature of the particular violin in question, determined as it is by the very range of body resonance frequencies and damping factors which plate-tuners are so concerned about. In addition we see why very high notes are less clearly discriminated - the separate flybacks in the transient are too close together, out of the effective parameter range for the precedence effect to operate. In fact, conversations with a psychoacoustician[4] suggest that the range of notes for which the original effect is clearly perceived fits in reasonably well with the known parameter range for the precedence effect.

I have only been able to test this idea by very casual experiments. If I take two violins which I can tell apart by the original blindfold listening test, it seems to me that I hear much the same quality difference between them when I damp the strings and flick the bridge of each to produce a 'clonk'. However, other factors certainly influence such discriminations between instruments, and it is hard to know from such casual tests how much these are affecting things. A systematic psychoacoustic experiment is needed here. I believe that standard techniques of factor analysis and so on could be used to map out the 'perceptual spaces' of a set of violins, both based on martelé notes and on clonks. If these perceptual spaces turned out similar, the idea would be confirmed. Anyone looking for a good project, please take note! I would be delighted to advise on details and to see the results.

Supposing for the moment the idea to have some truth in it, some interesting conclusions follow. One immediate one relates to the fact that, to my ears at least, it is easier to tell violins apart in the sort of blindfold listening test described than it is to tell guitars apart (even though I play the guitar and not the violin, so I am quite 'tuned in' to guitar sounds). Seen in the light of the precedence effect idea, this is simply a new form of the remark about preferring to hear the string quartet in a room - the precedence effect gives us better discrimination of those all-important clonks than the single offering of the clonk arising from a pluck transient.

There is a far more exciting consequence, though, which points to the future. If clonks are the thing, then it might well prove possible by careful analysis-synthesis work to find out something about what aspects of clonks are important for various perceived sound qualities. Clonks are after all far simpler sounds than violin music. This could lead directly to the crock of gold at the bottom of the plate-tuning rainbow, some positive information for the first time about how perceived qualities of instruments when played are related to body vibration modes, and thence to plate vibration modes, air coupling and all the rest. Note, as a preliminary example, that because of the low-frequency bias in the force spectrum of a single flyback clonks are dominated by the lowest few body resonances, which are the very ones attention has always been focused on in these pages. This idea shows in a specific way how those low-frequency resonances can strongly influence perceived sound quality in normal playing throughout a large part of the instrument's compass, well beyond where they influence steady notes. On that optimistic note I rest my case.

Acknowledgements and references

I am grateful to Brian Moore for psychoacoustical discussions, to Prof. L. Cremer for providing the spur to put this on paper, and to Michael McIntyre for his inevitably useful contributions.

1. I am using the term 'precedence effect' throughout this article in the generalized sense used by Benade[2]. As Prof. Cremer has pointed out to me, the term was first used to refer to the part of the phenomenon relating to directional perception by Wallach,Newman and Rosenzweig (Amer. J. Psychology 62 315,1949). The phenomenon was simultaneously pointed out by Cremer under the name 'law of the first wave front' (Geometrische Raumakustik, Hirzel, 1949). Discussion relevant to this article will be found in Cremer, Müller and Schultz 'Principles and applications of room acoustics', due out imminently from Applied Science Publishers.
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