TRANSIENT PHENOMENA IN MUSIC AND SPEECH

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INTRODUCTION

Transients are known to contribute to the recognition of a typical sound. Sound signals become unrecognizable if their beginning and end are smoothly suppressed. Many investigators have examined the transient phenomena; e.g. Stumpf (1910), Backhaus (1932) Trendelenburg and Franz (1935) and others all came to the afore mentioned conclusion with the aid of octave filters, oscillographs and a planimeter. They measured onset times and growth of the harmonics as important properties for speech and musical instruments. They stated a.o. that the onset time of flute and violin was rather long (100—200 m s) and of e.g. trumpet rather short (15 m s); the clarinet would have an intermediate position.

Recent investigations of a more psycho-acoustic character (Saldanha and Corso [1964] and Berger [1963]), deal with the importance of attack, steady state, release and vibrato of musical sounds in a rather restricted area of the musical frequency spectrum.

Our investigations deal with acoustical analysis with modern instrumentation and with psycho-acoustic evaluation as well of the aforementioned transient and steady state phenomena of musical instruments, with the intention for future research on speech. We repeated the older investigations with regard to the growth of amplitudes of harmonics in a series of specific sounds, produced by violin, double bass, flute, oboe, clarinet, bass-clarinet, bassoon, horn, trumpet, trombone.

METHOD

The sounds to be analysed were taken from phonographic record and equipment (Lenco L 77) or by live recording with an electrodynamic microphone (Sennheiser HN 421) recorded on tape (Revox G 36; Scotch tape 203). Often an infinite tape loop was used. Exploration was performed with an 1/3 octave filter (Bruel & Kjaer 2112)

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and a narrow band filter (Bruel & Kjaer 2105); the onset of the sound signal was reproduced on the screen of an oscilloscope (Tektronix 561 A) and photographed. Remark: The build-up time of the filter appeared to be negligible.

On the second track of the tape loop, a pilot pulse was recorded to mark the beginning of the sound in order to synchronize all the analyses pertaining to the same signal. A 100-cycle tone was reproduced as a time marker on the oscilloscope screen via the second beam. A Panoramic Sonic Analyzer (model A P-1) and a Kay Sona-Graph (6061 A) were used to obtain an overall spectrogram and a control of the relative importance of the harmonics.

Fig. 1 represents the blockdiagram of the apparatus.

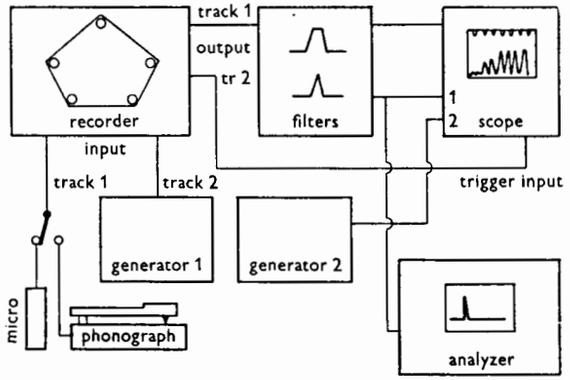

Fig. 1. Blockdiagram of the apparatus.

Fig. 2 gives an example of an analysis of the onset as a function of time (flute. pitch 880 cps). The arrow marks the moment where the onset is considered to be ended.

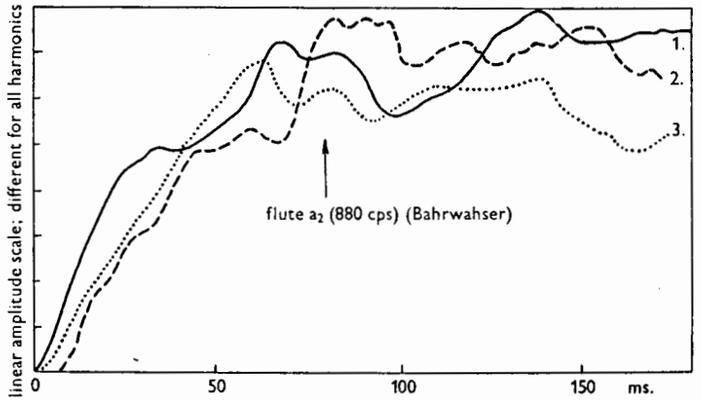

Fig. 2. Example of an analysis of the onset as a function of time. (Flute, pitch 880 cps). The arrow marks the moment, where the onset is considered to be ended.

There appears to be a specific relation between the growth of the harmonics and the pitch of the fundamental of a specific instrument. In first approximation, the growth is inversely proportional to the frequency of the fundamental; in other words:

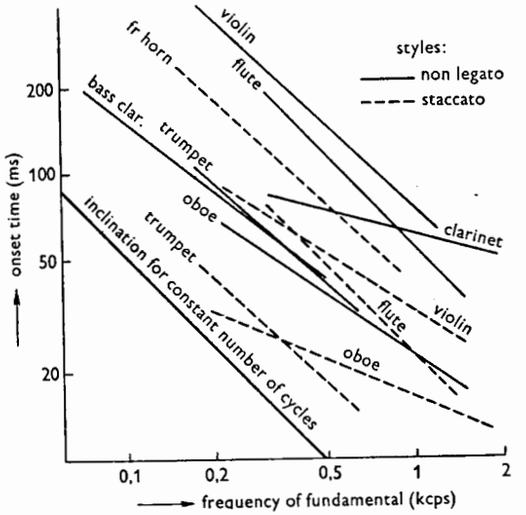

Fig. 3. Onset time as a function of frequency for different musical instruments, with the style as parameter.

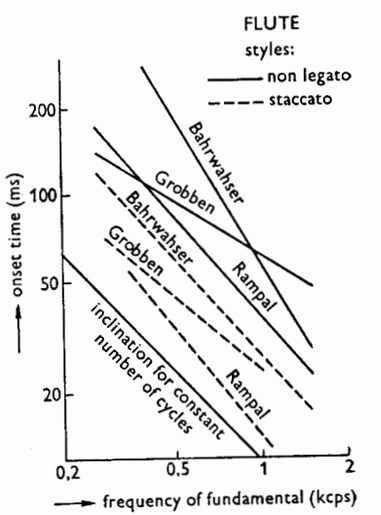

Fig. 4. Onset time for the flute for different players.

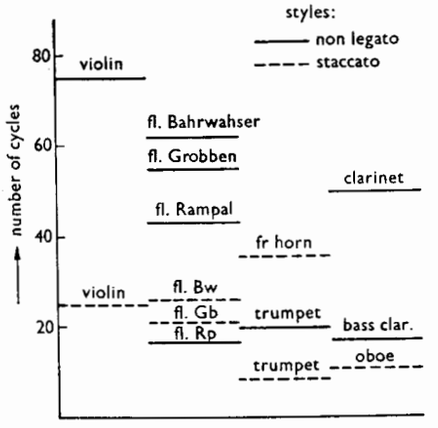

Fig. 5. Number of cycles necessary for the completion of onset for different instruments and styles.

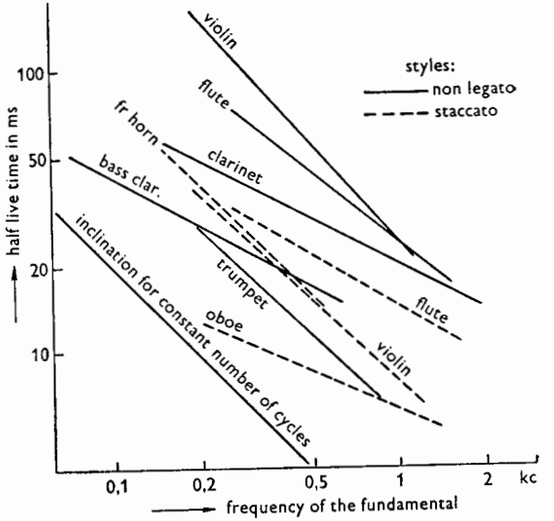

Fig. 6. Half-life time of the earliest harmonic.

the number of oscillations necessary for building up to steady state is constant for a specific instrument, with an additional influence of the artist's ability and style. There are, however, some deviations.

Fig. 3 gives the measurements for different instruments as a function of fundamental, with the style as parameter.

Fig. 4 stresses the importance of different players and style for one instrument (flute). The flutist Bahrwahser of the German School builds up his tone markedly slower than the French player Rampal; the author, amateur-flutist occupies an intermediate position as becomes a Dutchman.

Fig. 5 same data as in fig. 3 but now arranged according to the number of cycles necessary for a completion of onset for different instruments and players.

Fig. 6, 7 and 8 represent these same measurements again, but now from the point of view of half-life time of onset or appearance of the earliest harmonic.

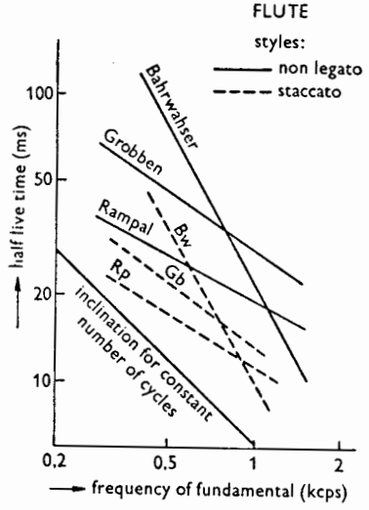

Fig. 7. Half-life time of the earliest harmonic for different flute players.

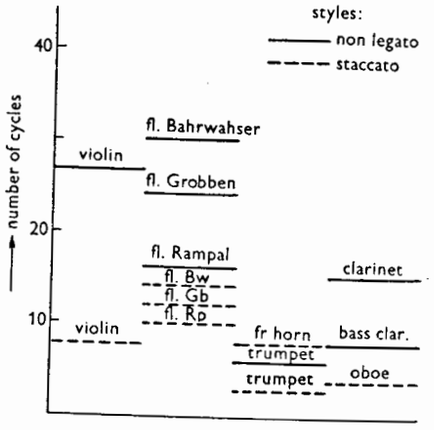

Fig. 8. Number of cycles necessary for reaching half-life time of the earliest harmonic. Parameter: instrument and style of playing.

DISCUSSION

Although Backhaus mentions the relation between pitch and onset-time, especially in the lower frequency range, up till now the fixed relationship between necessary number of cycles for the production of the tone and its pitch (depending further upon instrument, player and intention) has never been stated, as far as the present author knows.

It has to be mentioned here, that the present author has used as a criterion for decision whether the onset of the sound is completed, the behaviour of the strongest

partials, neglecting all partials, which are 20 dB or more weaker than the strongest one. According to our opinion, this seems to be a reasonable procedure, because: a) our results are reproducable within reasonable limits, b) they are roughly in agreement with the results of Backhaus and others, c) recognition of instrument seems to be determined for the major part by the appearance in the onset of the strongest partials, as has been verified by tentative investigations where an experienced team of listeners gave their opinion. The sound to be judged was given in a series of presentations of successive filtering; starting with presenting merely the fundamental. All measurements will be continued and extended e.g. in the analysis of the importance of envelope form. In a later stage speech will be analysed according to the procedure described.

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DISCUSSION

Filip:

I would like to ask whether also instruments of different quality but of the same type were investigated. If so, what results were obtained.

Fransson:

The formants of the double-reed wood-wind instruments are of great importance for the characteristic timbre of these instruments during steady state.

The formants of the speech vowels belong to the vocal tract but these formants are produced by the reeds, i.e. they belong to the source and not to the instrument. I think it would be of interest to know the building-up process of the formants during the transient period and investigate the influence of this process on the perception.

Sovijärvi:

The human articulatory organ as a musical instrument (using singing voice) has doubtless a very complex onset system. I would like to mention only one case: the vowel [*a*] after a voiceless plosive, for example in [*pa, ta, ka*], has after noise of the explosion an onset time of 10—20 msec. measured by means of contour spectrograms of the Voiceprint Spectrograph.

Ad Filip: I measured this only for the flute; Figure 4 and 6, but not with the particular intention of making a comparison. Lottermoser and others made these measurements for violins. I intend to do the same for other musical instruments.

Ad Fransson: I thank you for your comment. I certainly will think it over and carry out some measurements. Perhaps it is really better to measure formants than harmonics for particular musical instruments.

Ad Sovijärvi: I performed preliminary measurements on speech too and I found longer onset times. I am not yet sure about the measurements however.