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4aMU2. Transient phenomena in brass instruments
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The starting transient and the transition between notes are known to be of fundamental musical significance on all instruments. On a brass instrument the player needs to establish a strongly coupled resonance between the air column and the lips for a note to sound effectively. In the case of a slurred transient, the player must decouple the lips from one resonance before establishing the next. The ease with which this can be achieved depends on several factors including tube length and bore profile, and resonant modes being played. Analysis of measured mouthpiece pressure data and time domain computer modelling have been used to explore transient phenomena in brass instruments, with the aim of identifying desirable playing characteristics of an instrument.

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INTRODUCTION

When assessing the qualities of a musical phrase played on an instrument, the transient, either in starting a note or between slurred notes, is one of the most important features. The listener relies heavily on transients to distinguish between the sounds of different musical instruments. For a brass player evaluating an instrument, he or she will be concerned with a number of issues such as intonation, timbre, and the responsiveness of the instrument to start a note (ie the starting transient), and also the ease with which the player can move between notes, including slurred intervals (the slurred transient). A more complete understanding of the mechanics behind the complex coupled system of instrument and player, during a transition between notes, is of great importance in the wider explanation of what makes one particular instrument more satisfying to play than another instrument.

On brass instruments, the mechanics of the starting transient have been explored using optical techniques with both human players and an artificial mouth [1][2]. A natural progression from this work is to explore the mechanics of transitions between different notes.

In music, a ‘slur’ indicates a smooth transition between two notes; on a brass instrument, if these two notes are both resonant modes of the instrument, the player achieves this slur by a combination of changing the tension in the lips, mouthpiece pressure, and air flow rate. This is often referred to as a lip-slur. Previous exploration in this area includes impedance measurements for slurred transients in valved instruments [3][4].

To produce a lip slur, the player must move from one strongly coupled steady state vibration of lips and air column to another. It is expected that as the player changes the frequency of the lips in order to reach the target second note there will be a finite time during which the oscillations of the lips and air column will no longer be coupled. For both starting transients and slurred transients the transition time is known to be in the region of 50 to 100ms [1][2][5]. However, the mechanics of slurred transients have been found to vary in different registers of the instrument [7] and the work presented here explores this phenomenon further. By examining the pressure signal in the mouthpiece we can infer how the player produces an effective slur.

EXPERIMENTAL PROCEDURE

Figure 1 shows the experimental set up used to examine pressure signals of the radiated sound and that in the mouthpiece while slurring between notes.

![Figure 1. Experimental setup for transients experiments, simultaneously recording pressure in the mouthpiece and radiated pressure from the bell of the instrument.](image)

The instrument used for these experiments was a Meinl & Lauber/Paxman ‘baroque’ horn, modeled after an early 18th century orchestral instrument, and crooked in D (giving an overall length of approximately 4.4m) together with a commercially available PHC23a mouthpiece.
The radiated sound was measured using a 1/2-inch Sennheiser pressure-field microphone placed one bell radius from the plane of the bell of the instrument, while the pressure in the mouthpiece was measured using a 1/4-inch Bruel and Kjaer 4938 pressure-field microphone. The two pressure signals were simultaneously recorded using a solid state WAV recorder. The mouthpiece was modified to accommodate the 1/4-inch microphone, as is shown in Figure 2. A hole was bored in the mouthpiece cup to allow the microphone to fit into the wall of the mouthpiece cup, supported by means of a small brass collar. The microphone diaphragm was adjusted to be flush with the inside cup wall, and would have little effect on the playing characteristics of the instrument.

FIGURE 2. Horn mouthpiece, modified to accommodate a 1/4-inch microphone.

The tests were carried out with two experienced horn players. The players were asked to perform octave slurs between the 4th and 8th resonant modes of the instrument, and between the 8th and 16th resonant modes. For a horn crooked in D, such as this, these octave slurs are well within the comfortable playing range of a competent player. The results from both players were broadly similar. For consistency, only those from one of the players are shown here.

Using the instrument/mouthpiece combination described above, the input impedance envelope is relatively ‘flat’ over the low-mid frequencies; the resonant modes under investigation here are labeled on the input impedance curve. The amplitude of the 4th and the 8th modes are shown to have only a small difference in amplitude, with the 8th mode being approximately 1 MOhm higher than the 4th mode. However, the 16th mode has a significantly lower amplitude than the 8th mode.

FIGURE 3. Input impedance of the Meinl & Lauber/Paxman horn crooked in D, with PHC23a mouthpiece.
RESULTS

Figures 4 and 5 show the mouthpiece and radiated pressure signals for upward and downward octave slurs between the 4th and 8th resonant modes which correspond to the notes D3 and D4. The figures also show the instantaneous frequency of the pressure signal calculated using the fundamental frequency estimator program, YIN, detailed in [8]. The results display similar characteristics to those previously presented for both upward and downward lip-slurs over this octave [6]. For the upward slur, the instantaneous frequencies for both the mouthpiece and radiated pressures change almost instantaneously from the lower to the higher note. The pressure measured in the mouthpiece shows a significant drop during the transition, to around 0.5kPa, and the radiated pressure amplitude drops to almost zero for approximately 30ms. For the downward slur, shown in Figure 5, the transition is less well defined and the pressure amplitudes decrease to a lesser extent than those for the upward slur. The instantaneous frequency results for the mouthpiece pressure show some evidence of discrete steps in the frequency during the transition, which correspond approximately to the frequencies of the intermediate resonant modes.

FIGURE 4. Synchronised signals for lip-slur from D3 to D4 on the ‘baroque’ horn by Meinl & Lauber/Paxman. Top: Mouthpiece pressure, Bottom: Radiated pressure.

FIGURE 5. Synchronised signals for lip-slur from D4 to D3 on the ‘baroque’ horn by Meinl & Lauber/Paxman. Top: Mouthpiece pressure, Bottom: Radiated pressure.
Figures 6 and 7 show the results for upward and downward lip-slurs between the 8th and the 16th resonant modes, which correspond to the notes D4 and D5. This lip-slr is an octave higher than those previously discussed and spans the mid to high range of the horn. It is clear that there is not the same difference in characteristics between the upward and downward lip-slurs in this register; the upward slur no longer moves almost instantaneously between the two notes, as in the lower octave, but instead shows a more progressive transition, similar to that of the downward slur (Figure 5). There are seven clear intermediate peaks in the instantaneous frequency of both the upward and downward slurs, which correspond to the number of resonant modes between the played notes of D4 and D5. Although the transition over this range encompasses more intermediate resonances, the transition time for both the upward and downward slurs is approximately the same as for the lower register transitions: about 100ms.
DISCUSSION AND CONCLUSION

These results show that for an upward slur, in the lower register of the horn, the pressure amplitude of the radiated signal dies away to almost zero during the transition, and the mouthpiece pressure also diminishes significantly. However, the downward slur in the lower octave showed much less of a decrease in both pressure signals during the transition period. In the upper register the pressure amplitudes for both mouthpiece and radiated pressure signals show no marked diminution in amplitude during the transition for both the upward and downward lip-slurs.

The players were not aware of any change in technique when slurring in different registers; stating that their objective was simply to move as quickly as possible between the two notes and create a smooth sound. There was no audible break in any of the slur test results and the players confirmed that they were not aware of a reduction in amplitude during the transition. It is not yet clear why players appear to ‘catch’ resonances when slurring in either direction in the upper register, yet they are able to make an almost instantaneous transition upwards in the lower register. It is, however, interesting to note that these two intervals lie in very different parts of the envelope of the input impedance curve; the lower octave occurs over a relatively flat section of the input impedance envelope while the upper octave transition lies at a point where the resonances are decreasing significantly in amplitude.

REFERENCES