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The player-reed interaction during note transitions in the clarinet

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Abstract

When playing woodwind instruments, most of the player's control over the instrument takes place inside the player's mouth. Blowing pressure, tonguing strategies, embouchure and vocal tract configuration are modified during playing to perform expressively. Aiming at analysing the player's actions at the note transitions, an experiment with eleven clarinet players was carried out. The mouth pressure, the mouthpiece pressure and the reed oscillation were recorded in order to track blowing and tonguing actions and to identify vocal tract adjustments. The paper shows that the players adapt tonguing and blowing actions according to the dynamics and to the articulation style (legato, staccato). Similar patterns in the blowing technique are observed among most of the players, and some particular effects are described. The attack and the release transients are found to vary with blowing pressure. Moreover the release transients depend on the tonguing technique used to play articulation.

Keywords: Clarinet acoustics, Articulation, Performance analysis

1 INTRODUCTION

Single-reed woodwinds are the wind instruments in which the vibration of a single reed coupled to the resonance of an air column in a tube is responsible for the sound production; this includes the clarinet and saxophone families. The bore is the primary (linear) resonator of the instrument, where an air volume oscillates and radiates sound [6]. The tube's geometry determines the acoustic impedance of the instrument, thus allowing certain tones at the extended register, achieved when actuating a register key and/or by overblowing. The excitation mechanism (reed and mouthpiece) is a highly nonlinear element controlling the air flow into the instrument. The reed deflects against the mouthpiece, influenced by both the upstream (the player's respiratory system) and downstream (the resonator) air columns. The lower lip of the player (position and force) determines the vibrating length and the equilibrium position of the reed. Pressure-flow control at the player's mouth together with standing waves in the resonator lead to sustained oscillations of the reed [6].

In the view of this general description, one can discern several actions of the player's control over the instrument. Globally there are two locations where the sound can be modified: at the bore and at the mouthpiece. At the bore, the fingers control the pitch of the played tones, through tone holes and a set of keys [8]. Intonation issues and extended techniques (multiphonics, key slaps, rattles and other effects) might require particular finger manipulations [14]. At the mouthpiece, where most of the player's control in a wind instrument takes part, the blowing action, the embouchure (lips and jaws), the tongue-reed interaction and the vocal tract configuration combine efforts to create and modify sounds (Figure 1-left).

The first woodwind models and experimental setups considered only a part of this player-instrument interaction, namely the blowing action and the lip force. With this simplified player-control representation, reasonably accurate physical models and artificial-blowing setups were generated. Generally, the reed-mouthpiece behaviour is described in terms of mouth-to-mouthpiece pressure difference, reed opening and volume flow [5], with the lip force determining the equilibrium position of the reed oscillation. Recently, there have been two parallel lines of study to analyse the player-instrument interaction in single-reed woodwinds: determining the effect of the player's vocal tract on the produced sound [e.g. 15, 4, 13] and analysing the player's articulatory actions in different playing techniques [e.g. 1, 9, 12]. The latter is motivated by a need to characterise the transient phenomena that arise at the attack and release of tones, and has led to the first physical models of single-reed woodwinds with tongue-reed interaction [3].

In the current paper, we present some examples of the player-reed interaction taking place in the clarinettists'

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mouth that have been found after analysing the playing technique of 11 clarinet players. In a previous study, an exercise combining articulation techniques was analysed [12], and the relationship between blowing and tonguing techniques and the characteristics of transients was established. Motivated by the fact that a music exercise might provide less realistic music experience than a real clarinet piece, in the present analysis, some excerpts from a clarinet concerto are explored, in search for articulatory patterns leading to a significant modification at the transients between tones.

2 METHODOLOGY

2.1 Experimental setup

To analyse the player-instrument interaction in the mouth of clarinet players, an experimental setup is prepared. A Maxton NA-1 mouthpiece is mounted on a German B♭ clarinet (Thomann GCL-416 Synthetic Line) and equipped with sensors as follows (Figure 1). The mouth and the mouthpiece acoustic pressures are measured with two pressure transducers (Endevco 8507C-2; with Endevco model 136 amplifier). One transducer is attached to the side of the mouthpiece next to the reed, so that it reaches the player's mouth during playing. Another pressure transducer is inserted through a drilled hole into the mouthpiece.

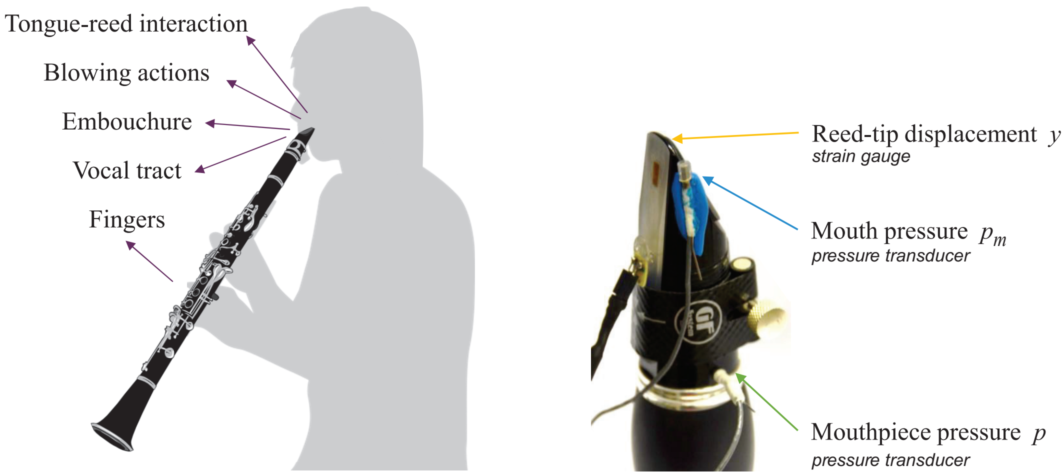

Figure 1. Left: Scheme of the main components of the player's control over the clarinet. Right: Experimental equipment on a German B♭-clarinet mouthpiece: pressure transducers for mouth and mouthpiece pressure measurements and strain-gauge on a synthetic reed to track the reed-tip displacement.

The tongue-reed interaction is tracked with a stain gauge on a reed (strength 2.5, German cut, by Légère) [7]. This sensor measures the deformation at the surface of the synthetic reed: when the reed vibrates, this sensor gives a voltage proportional to the tip-reed opening [11]. When the tongue contacts the reed, the sensor detects a lack of oscillation, thus giving the instances of tongue-reed contact and tongue-reed release with an accuracy of a few periods. Finally, the external sound is recorded with a microphone (d:vote 4099U, by DPA) mounted on the instrument. All signals are simultaneously recorded at 50000 Hz using a digital acquisition platform (NI 9220, by National Instruments).

2.2 Experimental design

Eleven clarinet players were invited to the music acoustics laboratory of the University of Music and Performing Arts Vienna and were asked to play articulation-related exercises and some music excerpts. Among the clarinettists there were 9 advanced students from the University and 2 professional players. For the current study, three excerpts showing a variety of articulation and dynamics were selected from the Clarinet Concerto n. 2 by Carl Maria von Weber (see an excerpt in Figure 2), a common clarinet solo part that was known by all participants.

Figure 2. Two measures from an excerpt selected from the Clarinet Concerto n. 2 by Carl Maria von Weber (Op. 74).

All participants performed on the same sensor-equipped clarinet. They were given about 10 minutes to familiarise themselves with the setup before the actual recording began. At the beginning of the recording of the excerpts, the players were given a tempo indication through a metronome-click at 108 bpm. The metronome was then turned off, in order to achieve more realistic concerto-playing conditions. Many players maintained the given tempo during performance (players 1, 5, 7, 9 and 10). Players 2, 3, 4 and 11 performed faster (about 120 bpm) and players 6 (102 bpm) and 8 (98 bpm) performed slower.

At the beginning of every experimental session, the participants were informed about the experimental procedure. Following the experimental protocol approved by the Ethics Committee of the University, the participants allowed anonymous usage of their data and gave written consent of their voluntary participation in the experiment, for which they received a nominal fee. Every session lasted for about 40 minutes to one hour. At the end of the session, the participants filled an anonymous form in which they were asked about their playing technique and music practice habits, as well as about their impressions during the experiment.

2.3 Signal conditioning and parameter extraction

The strain-gauge signal is calibrated to obtain the reed-tip displacement y during oscillation (see botom of Figure 3), as detailed in [11]. The displacement values given during tongue-reed contact are for indicative purposes only, since the deformation of the reed in presence of the tongue does not follow the same calibration curve. The mouth and mouthpiece pressure measurements are calibrated according to the manufacturer. These pressure transducers can measure both DC and AC values. In the mouthpiece, only an AC value is present (mouthpiece pressure p, in green in Figure 3), because the tube is open to the surrounding air. In the mouth, both DC and AC values are measured: the DC being related to the blowing actions (blowing pressure $\hat{p}_\mathrm{b}$; dashed line on top of Figure 3) and the AC to the resonance in the vocal tract (dynamic mouth pressure p_m; pale-blue in Figure 3). To obtain the blowing pressure $\hat{p}_\mathrm{b}$ (DC), a moving-average filter is used to low-pass filter the measured signal (using 6.8 ms time-windows). Then, the dynamic mouth pressure p_m (AC) is obtained by subtracting the blowing pressure $\hat{p}_\mathrm{b}$ from the measured signal.

The tongue-reed interaction is analysed in terms of the instances of tongue-reed contact and tongue-reed release, and the duration of the tongue-reed contact. To detect the instances of tongue-reed contact and release, the low-pass filtered strain-gauge signal is computed (solid line in the bottom of Figure 3). The tongue-reed contact instant is established as the maximum of its derivative (vertical solid lines in Figure 3), i.e. the instant when the reed displacement moves the fastest while closing against the mouthpiece lay. The tongue-reed release instant is found at the first zero crossing of the derivative after a minimum, i.e. the instant when the reed is back to the equilibrium position (vertical dashed lines in Figure 3). The tongue-reed contact duration T_c is obtained as the difference between these two instances.

The interaction between the player's mouth resonance (vocal tract resonance) and the reed can be assessed in terms of an energy comparison between the dynamic mouth pressure and the mouthpiece pressure, as in [13], for example by comparing the root-mean-square (RMS) of both signals. The vocal tract is able to drive the reed vibration [15, 4] when the energy of the vocal tract oscillation is comparable to the energy at the mouthpiece.

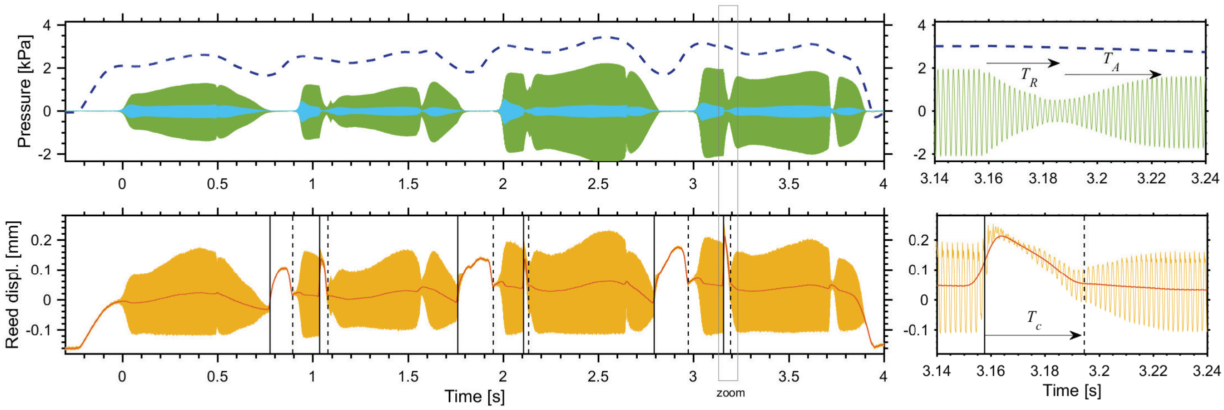

Figure 3. Signals measured for two measures of the performed Clarinet Concerto (music in Figure 2): blowing pressure, mouthpiece pressure, dynamic mouth pressure, reed displacement and low-pass-filtered reed displacement. Vertical lines indicate the tongue-reed contact (solid: instant of contact, dashed: instant of release). In the zoomed-in view (n. 2 in Figure 2), T_A and T_R indicate the duration of the attack and release transients and T_c indicates the tongue-reed-contact duration. Player 10.

In some advanced techniques, like playing a pitch bending, the mouth-pressure RMS might be much higher than the mouthpiece-pressure RMS [13].

Both the articulation technique and the blowing pressure affect the duration of the transients of the tones and the spectral content at the transients [12]. The transients are located at the part of a signal where the oscillations increase in amplitude (attack transient) or decrease in amplitude (release transient). The mouthpiece pressure is often considered to determine the duration of these transients (as indicated with T_A and T_R in Figure 3); also the external sound or the reed oscillation can also be used for that purpose. The duration of the transients is obtained by considering the instances where the envelope of the signal is at 5% and at 95% of its maximum at the attack transient and the analogous values for the release transient.

3 RESULTS

The players use blowing and tonguing strategies to regulate the dynamics of the music (piano, forte...), to obtain articulation techniques (legato, portato, staccato, accents...), and to start and stop tones. In [12] the authors analysed the same participants when playing a given exercise and observed the coordination of blowing pressure and tongue actions to stop the tones. When looking into the Concerto played for this study, some of the previous observations are consistent and new effects are found, because of the wider pitch range of the concerto compared to the exercise, and the broader variety of rhythm, tempo and dynamics.

3.1 Common blowing and tonguing strategies

Most of the players use a similar blowing-pressure pattern during playing. The blowing pressure is used to obtain the dynamics (piano, forte) written in the music and to regulate the dynamics within a passage. An example is shown on the top of Figure 4, where nine players are compared (two players are omitted in this comparison because they performed significantly slower). All players use a progressively increasing blowing pressure up until $t = 2.5$ s. The signals are synchronised so that $t = 0$ s corresponds to the beginning of the first attack transient (measured at the reed displacement). At this instant, the threshold of oscillation of the reed can be obtained: the blowing pressure values at $t = 0$ s (dashed lines at the top plots) show consistency among players (2-2.5 kPa); the small variability is introduced by each player's different embouchure settings, changing the effective reed stiffness.

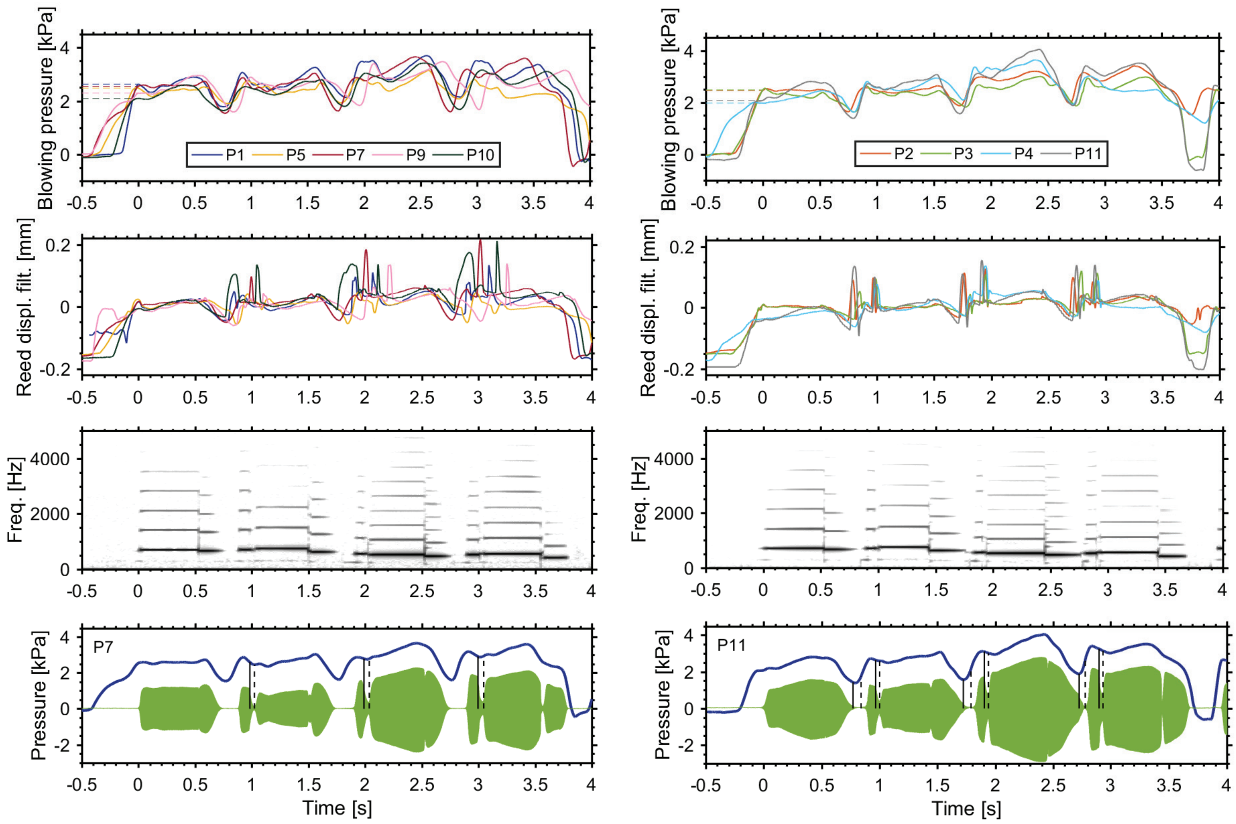

Figure 4. Blowing pressure and low-pass-filtered reed displacement compared among players (music in Figure 2). Right and left plots group the players with similar tempo. On the top plot, dashed lines indicate the blowing pressure at the beginning of the first attack transient. On the reed-displacement signal, the spikes show the tongue-reed contact. Mouthpiece-pressure spectrograms are plotted for player 7 (left) and player 11 (right). At the bottom, blowing pressure (blue) and mouthpiece pressure (green) with indication of tongue-reed contact (solid: instant of contact, dashed: instant of release) are plotted for these two players.

In Figure 4, the reed low-pass-filtered displacement (i.e. the reed averaged motion due to the changes in blowing pressure and tongue-reed contact) is plotted in comparison among players. In this signal, the spikes correspond to tongue-to-reed contact, when the reed rapidly closes against the mouthpiece. As observed before $t = 0$ s, most of the players did not use a tongue contact before the first tone onset (except for player 9). When playing legato ($t = 0.5$, 2.5 and 3.5 s) the players do not provide any tongue-reed contact.

Players combine blowing and tonguing strategies to stop and initialise tones [12]. Although there is no written pause in the music, players sometimes stop the sound with a decrease in the blowing pressure (as at $t = 0.7$ s in Figure 3 and 4). However, if the articulation must be fast (as in the staccato tones, at $t = 1$, 2 and 3 s), the reed vibration must be stopped with a tongue contact. For the selected passage, the 3 staccato-articulated tones (see * in Figure 2) are usually performed with 6 tongue strikes, right before and after every tone, as it appears very clear on the right of Figure 4. On the left, however, there is more variability in the tonguing technique, as some players only tongue at the end of the staccato tone but not at the beginning.

At the bottom of Figure 4, two players are compared. For this particular passage, no difference is found in the attack transient regarding whether they use the tongue before the staccato tone (player 11) or not (player 7).

The attack transients are similar in length (about $T_A = 30$ ms) and in spectral content in both cases. Player 11 uses the tongue to prepare the staccato tones, but this tongue-reed contact happens when the previous tone has already decayed (i.e. it is not used to stop the previous tone).

3.2 Other observations

It has been observed that many patterns can be identified in the performing style of all of the participants, however some particular effects are present in a few of them.

An exception of the observed blowing-tonguing coordination to play staccato tones is found in player 6. As shown in Figure 5, this player maintains a high blowing pressure during the whole passage, and stops the tones with a tongue contact. This results in a faster release transient previous to the tonguing ($T_R = 50$ ms), compared to players 7 and 11 (about $T_R = 100$ ms). Moreover as the previous tone is sustained, all the harmonics are present until the tongue-contact happens, and they decay simultaneously at the release transient (at $t = 1$, 2.1 and 3.2 s in Figure 5-right). Instead, in players 7 and 11 the harmonics decay progressively from high to low pitch (at $t = 0.7$, 1.7 and 2.7 s in Figure 4). Also when the blowing pressure is maintained high (player 6), the attack transient of the staccato tone raises faster in amplitude ($T_A = 25$ ms) and in harmonic content, than in the cases when it raises to create the next tone (players 7 and 11).

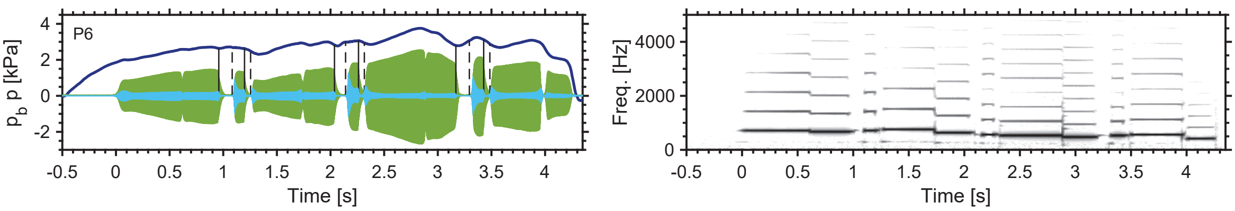

Figure 5. Left: Blowing pressure (blue), mouthpiece pressure (green) and dynamic mouth pressure (pale-blue) with indication of tongue-reed contact (solid: instant of contact, dashed: instant of release). Right: Mouthpiece-pressure spectrogram. Player 6.

Player 5 (orange in Figure 4-left) shows a blowing-pressure pattern similar to other players. However, the reed signal does not show spikes at the staccato articulation. This is because, for this particular clarinettist, the tongue-reed interaction happens much lower on the reed vibrating area than for the other participants, working in collaboration with the damping introduced by the lower lip (according to the description given by the player). Because the blowing pressure for Player 5 is similar with other players, the attack and release transients are also comparable.

A peculiar effect happens at the last note transition of the example passage (n. 2 in Figure 2). This note transition is written to be played in legato articulation, thus players show no tongue-reed contact ($t = 3.6$ s in Figure 3 and 4). However, the mouthpiece pressure presents a release and attack transient that would be assessed as portato articulation (with tongue) rather than legato articulation. The reason for this effect is that the note transition happens between two notes at different registers. Players might achieve a softer transition by adjusting their vocal tract, as observed in the saxophone [13]. In Figure 5, there is a significant increase in the resonance of the oral cavity at the end of the first tone (see pale-blue signal at $t = 3.9$ s); suggesting that the player might support the note transition with vocal tract tuning.

4 FINAL REMARKS

An experimental setup to analyse blowing and tonguing techniques during clarinet performance has been used to determine their effect on the note transitions when playing a Clarinet Concerto. An excerpt from the Clarinet Concerto n. 2 by Carl Maria von Weber has been used to illustrate such effects. The results are in accordance to the observations made when considering a predefined exercise [12]. As rhythm, dynamics and articulation vary during performance, players use a combination of blowing and tonguing techniques to perform expressively.

In the view of the presented observations, we can conclude that a tongue strike on the reed previous to a staccato tone does not seem to have an effect on the attack transient of the tone to be played, if the blowing pressure has been released. As suggested in [12], the attack transients are mainly affected by the blowing pressure. However, a tongue-reed contact before the staccato tones does have a prominent effect on the release transient of the previous tone if the blowing pressure is maintained high. Also a slight effect on the attack transient of the following tone has been observed: the attack transients are shorter when the blowing pressure is maintained at a high level during playing.

A similar methodology, based on mouth and mouthpiece pressure and reed bending measurements, has been used to study articulation in other woodwinds instruments [8, 10]. And it has also been used to provide reference signals to implement inverse modelling of clarinet sounds including tongue articulation [2]. Both the music acoustics and the music education fields could benefit from such a methodology to observe and describe the phenomena taking place during articulation in clarinet and saxophone performance.

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