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Zooming into saxophone performance: Tongue and finger coordination

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On the saxophone, the player has to coordinate articulatory tongue actions with the finger movements at the keys. Finger-key actions are used to modulate the sounding frequency. In contrast to clarinet keys, the saxophone key cushion covers the tonehole completely, so the arrival position of the finger to the key does not influence the sound directly. To investigate finger-key interactions, we improved our existing sensor saxophone setup: additional acceleration sensors track the key movements and a webcam captures the left-hand fingerings of the player. Ten graduate saxophonists played a 24-tone melody in a synchronization-continuation paradigm. We calculated the timing precision of each performance from the reed signal. Detailed examination of the recorded videos showed that the fingering positions differ extremely between subjects. Subjects who covered the key pearl with their fingertips completely achieved better results in timing precision than the average group. Although we assume that the saxophone fingering technique influences the performance, we suspect other playing parameters like tonguing, breathing, and embouchure to have more impact on the overall performance quality.

Keywords: saxophone; articulation; fingers; coordination; measurements

In saxophone performance the player has to coordinate articulatory tongue actions with the finger movements at the keys. Depending on the musical phrase, onset timing is controlled by the fingers (legato playing), the tongue and the fingers (portato, staccato playing), or the tongue alone (tone-repetitions; Krautgartner 1982, Liebman 2006). We showed in a previous study that portato playing was more accurate with combined tongue-finger actions

than with only tongued tone repetitions (Hofmann *et al.* 2012). These findings support the theory that temporal stability improves with movements produced by multiple effectors (Ivry *et al.* 2002).

This study focuses on the examination of fingering positions and reports on improvements of the measuring methods for saxophone performance analysis. To clarify observed artifacts in our previous finger-force measurements, we added acceleration sensors to the saxophone keys and mounted a webcam on the bell of the saxophone to capture the motion of the fingers.

METHOD

Participants

Four female and six male graduate saxophone students (different from Hofmann *et al.* 2012) from the University of Music and Performing Arts Vienna (n=10, mean age=23.6 years, range=21-33 years) participated in our study. On average, they were playing the instrument for 11.1 years (range=8-20 years) and were practicing 1.6 hours per day (SD=1.06). Four participants played classical music only, four played only jazz/rock/popular music, and two were active in both musical domains. Participants were paid a nominal fee after the experiment.

Materials

The stimulus material was the 24-tone melody from Hofmann *et al.* (2012). All participants played on an E-flat alto-saxophone, which was equipped with sensors to monitor the saxophone performances: A strain-gauge was glued onto the reed to measure articulatory tongue impulses (Hofmann *et al.* 2013). Force sensors on the key pearls measured left-hand finger force, additional acceleration sensors (Piezzotronics: PCB 352C23) tracked key-movements, and a web-cam mounted to the saxophone bell captured the motion of the fingers.

National Instruments (LabView) hardware and software was used for multi-channel recording (sampling rate=11025 Hz).

Procedure

The participants performed the melody with portato and staccato articulation in three different tempi, timed by a digital metronome on each quarter-note beat. Each trial contained two repetitions of the melody together with the metronome click. After the metronome stopped the players continued to play

according to the introduced tempi (slow=120 bpm, medium=168 bpm, fast=208 bpm). We recorded two trails per tempo condition.

Data processing

Reed

Characteristic landmarks were identified in the sensor reed data: a tongue-reed contact (TRC) occurred when the reed vibrations were stopped by the tongue (note-off). When the player's air-pressure remains constant, a release of the tongue (tongue-reed release, TRR) enables the reed to oscillate again (note-on). A landmark detection function (D11D10D9D8), based on wavelet-decomposition of the reed signal, was used to set TRC and TRR markers automatically in all sensor reed recordings (Hofmann *et al.* 2013).

Additionally a pitch analysis of the reed signal was made (AubioPitch Vamp Plugin to Sonic Visualizer; Brossier 2013) to verify the number of a note in the sequence by its frequency.

Keys

Key movements were extracted by thresholding sub-band (D9) of the acceleration data. The wavelet-decomposition had similar parameters as described in Hofmann *et al.* (2013).

RESULTS

Video capture of fingerings

The artifacts in some subject's force measurements can be explained by inspecting the recorded video: sometimes the saxophone keys were closed by the fingers not covering the key-pearl and thus not triggering the attached force sensor. Figure 1 shows screen-shots of individual players closing all left-hand saxophone keys. Some players (left pictures) cover the key pearl with their fingertips but others (right pictures) only touch a part of it. There seems no direct influence of the fingering position to the sounding outcome, because the key-cushion closes the tone hole independent of the particular properties of the finger action, but we suspect an influence on the timing precision.

Fingerings and timing precision

The time interval between two consecutive TRR landmarks was defined as the interonset interval (IOI). The IOIs during synchronization phase were close to the metronome rates: at slow tempo IOI=249.4 ms (metronome=250 ms);

Figure 1. Screen shots of four participants, with fingerings for g' on alto-saxophone. Depending on their playing technique, they cover the force sensors (left) or only touch a part of it (right). (See full color version at www.performancescience.org.)

medium IOI=178.3 ms (given=178.6 ms); and fast IOI=147.2 ms (given=144.2 ms), and shows that the players could synchronize well with the metronome.

Timing precision

We computed the variability of the IOIs in the continuation phase, by the coefficient of variation (CV, defined as $SD_{ioi}/Mean_{ioi}$) for each melody phrase and tempo condition. The CV can be seen as a measure of how equally distributed note onsets were played.

Table 1 shows the timing variability of all video recorded subjects. We assume that there is a light influence of the fingering technique on the precision of the performance. The subjects showed in Figure 1, who covered the key pearl completely with their fingertips, achieved a better score in timing precision (CV<8.8) than the average group (CV: M=12.06, SD=2.8).

DISCUSSION

Through video investigations we were able to answer open questions from our previous study and can now better explain the large differences in our finger-force measurements on the key pearls. Our hypothesis that the angle and position of finger-key contact is highly variable among different saxophonists was confirmed by monitoring the fingering video captures.

Table 1. Timing precision for new participants (11-20) with video captured performance.

Participant ID	*11*	*12*	*13*	*14**	*15**	*16*	*17#*	*18*	*19*	*20#*
CV of timing in %	13.12	13.53	11.88	8.8	7.54	10.22	17.27	11.23	14.13	12.85

Note. *Refers to the left pictures in Figure 1; #refers to the right pictures in Figure 1.

Although fingerings might influence the performance quality, we suspect other playing parameters like tonguing, breathing, and embouchure to have more impact on the overall performance quality.

This research is work-in-progress. A detailed examination of all collected data (e.g. acceleration data from the keys, bending signal from the sensor reed) is foreseen.

Multi-sensor investigations of performances on the saxophone deliver valuable insights into the complex interaction of tongue and finger actions and may also be applied to clarinet and other woodwinds.

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