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Practice makes less imperfect: the effects of experience and practice on the kinetics and coordination of flutists' fingers

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ABSTRACT

The key systems of woodwind modern instruments minimise the need for cross fingering in lower registers. Nevertheless, performance often requires near-simultaneous movements of several fingers, often with some digits rising while others fall, especially in performance in the high registers. We measured the individual finger movements of a group of amateur and professional flutists as they played an original piece unseen before the experiment. They played a modified flute with a position detector mounted below each key. The detectors, via an interface and computer, gave the timing and speed of each key, as reported in an earlier study (Almeida et al., 2009). Here we report the changes in speed and coordination between sight-reading and performance after a short session of practice. We also report the variability among players within each group, and the differences between amateurs and professionals

INTRODUCTION

The long process of learning a musical instrument implies the acquisition of many different actions or gestures that are implied in a fine control of the sound produced by the instrument. In many cases, lengthy repetition of gestures that are commonly used in a particular style of music is required. For instance, in many tonal instruments in classical European music, musical scales and arpeggi are repeated a large number of times over the whole career of the musician, even after he or she becomes a professional player. This training is necessary to maintain the coordination and reflexes necessary to play note sequences that appear often in their repertoire.

In a woodwind instrument such as the flute, among the main gestures implied in the performance we can cite:

- adjustments of the velocity, direction and width of the jet (Coltman, 1976) and
- speed and coordination of finger motions.

Achieving appropriate control of the jet is one aim of beginners on the flute as they try to master the intonation, intensity and timbre of each note using control variables that must be adjusted for each note in order to produce a homogeneous sound throughout the playing range of the instrument (de la Cuadra et al., 2005).

Fingering control is another important aim. Good coordination of the fingers is essential to play fast musical passages, and scales and arpeggi are usually rehearsed to prepare sequences that will later be performed in a musical context.

Even in instruments, such as the piano, on which a note is produced by the motion of a single finger, the accuracy and speed of a musical phrase are determined by the "freshness" of coordination and reflexes (Bresin & Batel, 2000).

Woodwinds have an added complication: they rely on the opening of lateral holes to change the effective length of the instrument and thus the note the instrument plays. These holes are open or closed by the direct or indirect action of the fingers. In many cases, two or more fingers must move to pass from one note to another. Since each combination of open and closed holes corresponds to an acoustic configuration of the resonator, it is easy to imagine that a poor coordination of finger movements has consequences on the transient sound between notes. Previous studies have considered the acoustical aspects of every possible fingering in the flute (Botros et al. 2002) and of the acoustical effects of non-simultaneous finger motions (Almeida et al. 2009). The latter includes a study on the speed and coordination of players in note transitions involving the motion of different numbers of fingers and in short musical pieces.

In this work, we analyse the performance of amateur and professional musicians in more common musical contexts, including sight-reading for a musical performance. These two contexts are compared, and we propose reasons for different finger coordination performance in the two cases.

MATERIALS AND METHODS

This study used a modified flute that is described by Almeida et al. (2009). (Other methods of key motion monitoring for musical performance have been reported, for example, by Ystad and Voinier, 2001 and Palacio-Quintin, 2003).

Here, reflected infrared sensors were installed under each key that is operated directly by a finger. These continuously measure the (analog) position of each key as functions of time. The sensors are sufficiently light and small that they do not disturb the normal playing of the flute. The cables that bring the signal to the recording hardware, however, increase the mass noticeably and can change the feeling of holding the flute. However, most of the players that participated on the study reported feeling comfortable after a few minutes getting used to the instrument.

A group of 5 musicians, divided into 2 professionals (concert player or teacher) and 3 of intermediate level participated in this study. They were asked to play an original musical piece as a first-sight reading, then were allowed 15 minutes of practice and finally to perform the piece as if in a concert. The piece (see appendix) is of no musical interest: it was specifically written to require several note transitions in which multiple finger movements are involved, sometimes with fingers in opposite directions. It also included some syncopation and accidentals so that it was not a trivial exercise in sight-reading. They had no prior knowledge of the score. They were asked to use, as much as possible, standard fingerings, and in some cases, given the exact fingering expected for one note. With these constraints, a 'maximum comfortable tempo' was requested for each trial.

The full performance was recorded in a small room treated to reduce noise and reverberation. Two microphones were used, one in a stand in front of the musician, above the score, the other clipped to the flute, about 10 cm from the embouchure. Simultaneously, the 15 signals for the positions of the keys acted on by a finger were digitised and recorded in a computer via a MOTU analog-digital interface.

The key signals were than analysed, using the procedure described by Almeida et al. (2009), to detect key opening and closing times. From the sound track, the durations of note transitions were extracted, and played notes compared to the musical score. Key transition data were aligned with the sound track in order to associate key movements to each note transition.

RESULTS

Overall analysis over a performance

We first analyse the performances in terms of correct notes and fingerings. In Figure 1, we represent the number of notes that match the original score for each trial. For each intermediate (I) or professional (P) musician, statistics for the two trials (1st Sight or Final) are shown. In some cases, additional pitches are sounded very briefly between two expected notes. These were not counted as mistakes, but are seen as transients produced by the fingering transition.

We then divide correct notes into the ones that were produced using the 'expected fingering' and those that were produced using an alternative fingering. Correct fingerings with incorrect notes represent very few cases where the note was produced using the wrong resonance of the instrument. Figure 2 shows the time used for completing the performance in each trial. Different interpretations seem to have been adopted by each musician, in particular for the two professional musicians. In particular P1 preferred speed to accuracy in the requested fingerings, whereas P2 concentrated on the requested fingerings, compromising slightly the speed. It is also apparent that the intermediate players have different levels, based on accuracy and performance speed.

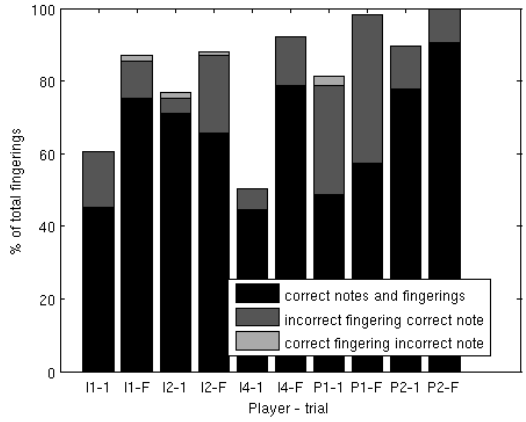


Figure 1: Percentage of expected fingerings for each performance. The total number of note transitions for each performance is 117.

An idea of the overall performances of the player can be obtained using a compact view of a few diagnostics performed on the measurements.

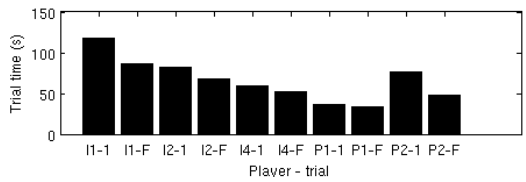
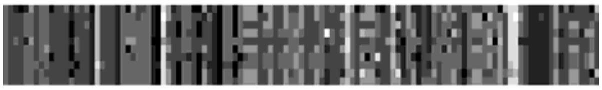


Figure 2: Duration of each trial

The errors are shown explicitly in the matrix below, where rows represent individual performances in the same order (top first) as figures 1 and 2. The 117 columns correspond to the sequence number of the note in the musical score. The colour code is that used in figure 1, where a white square again represents a mistake both in note and fingering.

The next figure, which has the same column and line configuration, represents the number of keys moved as a colour code for each note. These range from 0 (black) to 7 (white). The first line, separated from the others, represents the expected number of fingers moved for each note in the score.



A third matrix represents, for each note transition, the delay between the first moved key and the last moved key in each transition. The grey scale ranges from 0 (black) to 50 ms (white). Beyond 50 ms, the duration is always represented in white. 24% of the total number of recorded transitions had delays greater than 50 ms.

The fingering delays in the first sight reading and the final performance for each player are compared by plotting (Figure 5), for each transition, the transition time for the final performance against that for the same transition in the first sight-reading. The figure distinguishes note transitions in which all fingers move in one direction from those in which some fingers move in opposition to others.

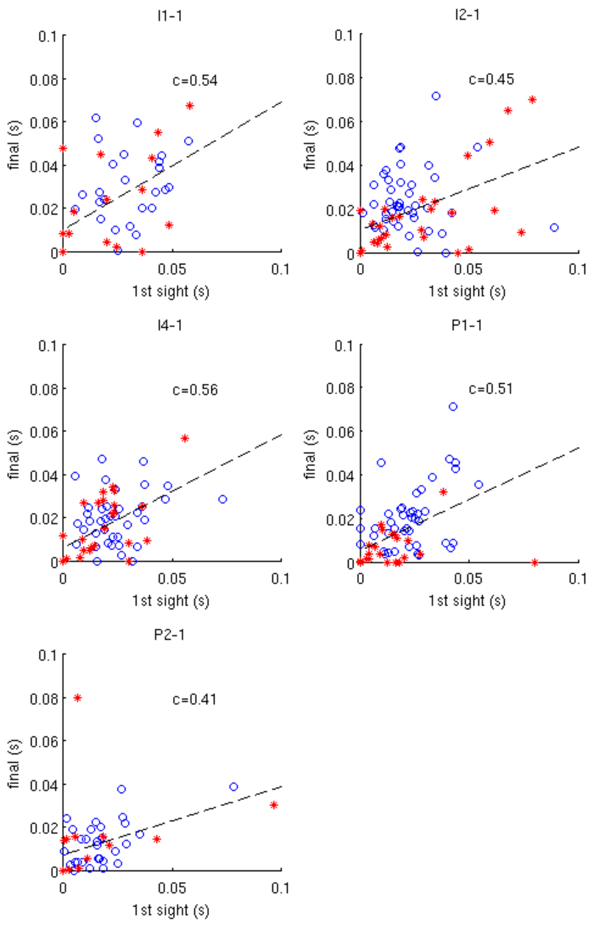


Figure 5: Duration in seconds of fingering transitions on first sight trials plotted against the corresponding in the final performance. Plot separates the transitions having fingers moving in opposite directions from those in which all fingers move together.

Figure 5 shows that, as expected, transitions with unidirectional movement are usually faster. Figure 5 also shows a correlation between transition times in the first sight-reading and final performance. However, this correlation is by no means perfect. The scatter suggests that the transition time does not depend very strongly on the context of the transition in the piece. How to explain the non-zero correlations, which is typically 0.5? It is possible that some transitions may be difficult because of their context, either because of the series of fingerings that form that context, or because the player is, at that point, distracted by other difficulties.

Figure 6 represents a statistical analysis of the transition time as a function of the numbers of fingers moved and whether or not fingers moved in opposite directions. The boxes correspond to quartile durations (transition durations for which the delay ranges between 25% and 75% of the total transitions in each category) and the middle line is the average delay for each category. The error bars represent the total extent of the delays considered for the statistics, and the few crosses the outliers that were not taken into account. Only 2 and 3 finger transitions are represented. Transitions with more fingers were less common in the piece, and they do not show clear differences between first-sight and final trials.

When a small number of fingers are involved, consistent differences are observed between the first and final trials. A regular and natural pattern is that note transitions that involve fingers moving in opposite directions are performed substantially faster in the final trials. This difference is not so clear-cut in the first-sight readings even though averages follow roughly the same trend.

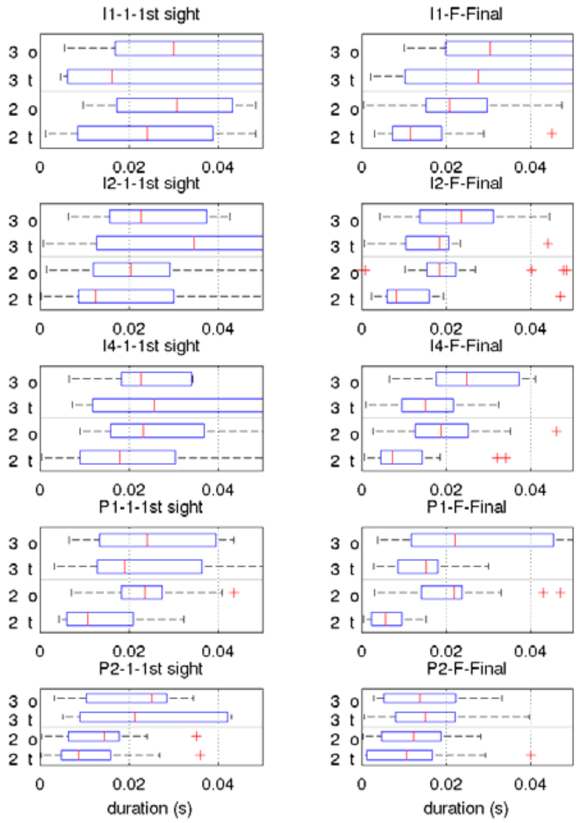


Figure 6: Statistical view of the finger motion delays for transitions involving 2 or 3 fingers moving in the same direction (t) or in opposite directions (o). Boxes represent quartile positions and the central line the average. Crosses represent outliers not taken into account for the statistics (see text).

In general, the average delays are slightly shorter in final performances, and the spread around the average is smaller, indicating that the players are more accurate than in first sight-readings, especially the intermediate level players. This may be related to a higher concentration on reading in the first-sight trial. The fact that the difference is higher in the intermediate group gives a hint that the finger transitions are less automated by years of practice in this group than in the professionals.

Detailed analysis of a finger transition

In a previous study (Almeida et al., 2009) it was shown that some non-instantaneous finger movements are 'unsafe', meaning that they may produce unwanted transient effects in the sound, depending on the order of movement of the fingerings. One case is the transition between F6 and F#6, involving the right index and ring fingers. When an intermediate configuration has both of these fingers raised, the oscillation in the resonator is harder to maintain due to an absence of a strong bore resonance close to the frequencies of F6 or F#6. It was shown that intermediate players particularly tended to avoid this situation on musical exercises, and that professionals tend to be more synchronous, staying within 10-20 ms of simultaneity.

In this section we compare the performance regarding these two fingers in the first-sight and the final trials of the musical piece studied in the previous section. Here the time delay between the depressing a key and releasing the other is analysed. A positive value for the interval means that both keys are depressed during that interval (safe transition), and a negative value means that both keys are open during that interval (unsafe). We also represent other note transitions that involve the same keys moving in opposite direction but do not have the same 'safety' concern, either alone (for instance F4-F#4 or F5-F#5) or together with other keys.

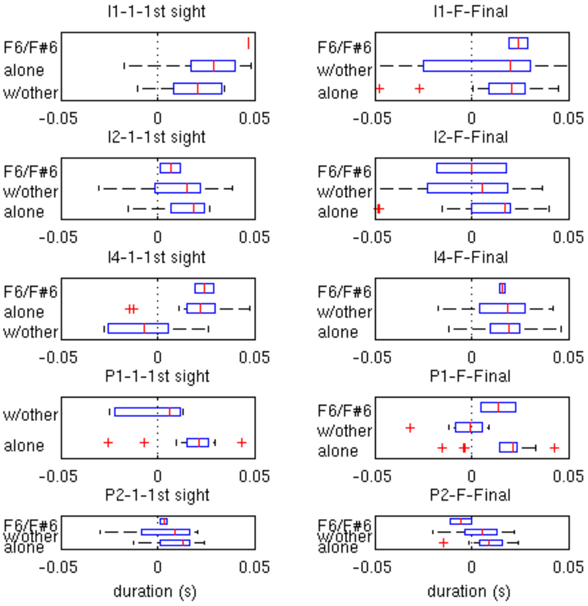


Figure 7: For F6, the index and little fingers of the right hand are down, the others up. To pass to F#6, the index finger rises and the ring finger is pushed down. For this transition, the top row in each figure plots the time at which the ring finger moves minus that at which the index finger moves. The same finger motion is used in other note transitions, alone or with fingers. These data are shown in the next two rows.

Here, the differences between trials are small. The figure shows however that the tendency to use the 'safe' fingering does not depend considerably on the actual note transition involved. This may be an indication that musicians have learned (whether consciously or subconsciously) that having both keys closed rather than open is a safer option.

CONCLUSIONS

During this work, an automatic method was developed for associating an analysis of recorded sound to finger action during a musical performance.

In a first stage, differences were identified in the level of the performances. A comparison of speed and mistakes allows one to rank players on this aspect of playing. In some cases a better performance in terms of transition time represents more mistakes in terms of the requested fingerings.

The durations of fingering transitions along the score are usually somewhat correlated between first-sight to final readings. In general, the average and standard deviation of fingering durations is reduced from the first to the final reading. Musicians may compromise accurate finger motion in favour of a higher concentration on the reading and interpretation process.

Musicians tend to avoid the unsafe transitions, i.e. those in which multiphonics, broad band noise or wrong notes may briefly sound during the transition, in what is probably an acquired gesture. However, it was shown previously (Almeida et Al., 2009) that in most cases the unsafety in these transitions can be avoided by using a correct embouchure. This allows musicians to use more simultaneous transitions once they have a correct embouchure. A study combining finger analysis to embouchure analysis could test this hypothesis.

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APPENDIX

Score