Mastering the violin: Motor learning in complex bowing skills

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A pilot study is presented comparing the performance of complex bowing patterns of three violinists. Analysis of the movements revealed a subtle coordination between string crossings and bow changes in repetitive bowing patterns across two and three strings. Clear differences between the performances of the three players were found that could be interpreted in terms of consistency and efficiency of movement. The pilot study forms an upbeat to a planned study to characterize the motor learning process in bowing skills from intermediate to expert level.

Keywords: violin; bowing; movement; motor learning; practicing

The violin and other bowed-string instruments are known to be difficult to master. This can for an important part be led back to the critical constraints involved in the sound generation process, which require a precise spatiotemporal control of bowing actions (Rasamimanana 2008, Demoucron 2008, Schoonderwaldt 2009). The development of the necessary motor skills involves many hours of practice under critical guidance by the ear. However, not much is known in any detail about the motor learning processes that take place, in short term during practice, as well as in the long term in the development toward expertise.

Studies of motor control in bowed string performance have mainly been dealing with expert performers (Winold et al. 1994, Shan and Visentin 2003). Recent studies have explored the use of modern motion analysis techniques in string pedagogy (Konczak et al. 2009, Visenting et al. 2008, Larkin et al. 2008, van der Linden et al. 2011). However, the focus of these studies has mainly been limited to relatively basic bowing skills (e.g. legato playing and the development of a straight bow stroke) and novice performance.
Currently, there is a lack of studies dealing with the learning of complex bowing skills, which form an essential part on the way toward expertise. The main objective of the current study is to address these issues and to gain more insight in motor learning and refinement in a range of complex bowing skills. The focus is on the development from intermediate to expert level. An important aspiration is the generation of pedagogically relevant findings, which in the long term could lead to optimization of practicing and teaching strategies in professional education.

In this article, a pilot study is presented of a particular class of complex bowing patterns. The movements of the bow relative to the violin were recorded using a motion capture system. An analysis is presented of repetitive movement patterns in fast 16th-note passages involving coordinated bow changes (reversal of bowing direction), and string crossings.

**METHOD**

**Participants**

Performances of three violinists were analyzed for this study: two advanced music students (player 1 and 2) and one amateur player (player 3).

**Materials**

A 3D motion capture system was used to measure the position and the orientation (6 DOF) of the bow and the violin. An additional sensor was used for measuring the bow force. This method allowed for a complete measurement of the bowing parameters used by players to control the sound (Schoonderwaldt and Demoucron 2009). The movements of the bow were transformed to the (moving) local coordinate system of the violin.

**Procedure**

Performances of the first 28 bars of J. S. Bach’s *Preludium* from the third Partita for Solo Violin (BWV 1006) were recorded. One of the advanced students (player 1) was familiar with the piece; the other student (player 2) was sight-reading; the amateur player (player 3) was also familiar with the piece. The analysis focused on the spatiotemporal coordination of string crossings and bow changes in two types of complex repetitive bowing patterns (see Figure 1). Both fragments are played détaché: in fragment 1 two strings are alternated, fragment 2 is played as an arpeggio across three strings.
RESULTS

The two types of complex bowing patterns correspond to spatial trajectories of the bowing hand in the shape of a circle and a figure-of-eight, respectively, as illustrated in Figure 2.

The coordination between bow changes and string crossings in the circular bowing patterns was illuminated by a derivative representation of bow inclination (the bow angle relative to the violin used to select the string) versus bow velocity (velocity of the bow perpendicular to the string). Figure 3 reveals a clear hysteresis in the patterns of all three players, which indicates that the string crossings occur slightly earlier than the bow changes (zero bow velocity). This may seem surprising at first; intuitively one could expect that string crossings and bow changes should co-occur. However, taking the mechanics of the bowed string into account, this behavior could be explained by the fact that a minimum amount of bow force is required for a proper start of a tone (Guettler 2002, Schoonderwaldt 2009). Thus, the lead of the string crossings
Figure 3. Plots of bow inclination versus bow force showing the performances of fragment 1 (circular bowing pattern) by all three players.

represents an optimized strategy related to the transfer of bow force between strings, which is necessary for the production of clean note transitions.

Figure 3 also reveals some subtle differences between the players. The pattern produced by player 1 formed a rather regular ellipse, which indicates a constant phase relation between the two movement components. The sharp cusp visible in the patterns of the other two players, most notably player 3,
reveals the presence of variations in the relative phase, which might be an indication of a less efficient movement pattern.

The figure-of-eight pattern, which is considerably more difficult to produce, revealed greater differences between players. Player 1 (see Figure 2) produced the most stable pattern, characterized by a similar lead of string crossings as demonstrated in the circular pattern. The performances of player 2 and 3 are shown in Figure 4. Player 2 (sight-reading) was not able to produce a stable performance at all. Player 3 (amateur) was able to perform the passage but was less consistent than player 1 and had much less control of the coordination between string crossing and bow changes. It could be confirmed by listening to the recording sound that the note transitions were less well defined and noisier. Furthermore, it can be seen that player 3 exhibited a larger amount of “overshoot” on the outer strings (string I and III) compared with player 1, indicating a less efficient movement for making string transitions.

**DISCUSSION**

The pilot study revealed clear differences between the performances of the three players. The differences could be interpreted in terms of consistency (regularity of the pattern) and efficiency (variations in relative phase between movement components, movement amplitude related to string transitions). Furthermore, it was found that a few features were sufficient to characterize the complex bowing gestures described in this study—namely, the relative phase between two periodic movement components and the amplitude of the movement associated with string crossings.

In the near future a cross-sectional study is planned to describe long-term development of a representative set of bowing skills in violinists during the course of professional music education. Similar sets of features will be defined for an adequate performance characterization, allowing for comparison between individuals and groups. In addition to the movements of the bow relative to the violin, which have a direct relation to the control of the sound, the movements of the bowing arm will be analyzed in order to gain insight in the physical production of tone in bowed string instrument performance. A long-term goal of the studies is to provide a contribution to more effective teaching and practicing strategies.

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