Effects of different bow stroke styles on body movements of a viola player: an exploratory study

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ABSTRACT

This paper describes an exploratory study of different gestures and body movements of a viola player resulting from the variation of bow strokes length and quantity. Within the theoretical framework of embodied music cognition and the study of musical gestures, we aim to observe how the variation of a musical feature within the piece affects the body movements of the performer. Two brief pieces were performed in four different versions, each one with different directions regarding the bow strokes. The performances were recorded using a multimodal recording platform that included audio, video and motion capture data obtained from high-speed tracking of reflective markers placed on the body of the performer and on the instrument. We extracted measurements of quantity of motion and velocity of different parts of the body, the bow and the viola. Results indicate that an increased activity in sound-producing and instrumental gestures does not always resonate proportionally in the rest of the body and the outcome in terms of ancillary gestures may vary across upper body and lower body.

1. INTRODUCTION AND THEORETICAL FRAMEWORK

Gesture and body motion in music performance have recently received increasing interest both in academic research and artistic practice. The subject has been addressed by researchers from multiple disciplinary fields, giving rise to a continuously developing interdisciplinary theoretical apparatus [1, 2, 3]. New insights have led to define music perception as *embodied* (tightly linked with bodily experience) and *multimodal*, meaning that music is experienced not only through sound but also by way of visual cues and sensations of motion, effort and dynamics [4]. These aspects are at the core of the paradigm of embodied music cognition (EMC) [5] within which the body is understood as a mediator between the physical environment (where music moves as sound waves in the air) and the subjective musical experience (one's feeling in response to music). By acting as a mediator, the body will build up a repertoire of gestures and gesture/action consequences, or what Leman calls a *gesture/action-oriented ontology* [6]. This repertoire can be considered as a collection of movements made to achieve a particular goal (actions) linked with the experiences and sensations resulting from such actions. Musical gestures are at the core of this repertoire and the coupling of actions and perceived sensations forms an engine that guides our understanding of music. Overall, we could say that *gestures are a vehicle for the construction of musical meaning*.

Gesture has in fact become a key concept in music research, even though its definition appeared initially vague and sometimes problematic. Within the musical domain, Cadoz and Wanderley [7] review various definitions of gesture and proposed different classification of gestures including *instrumental gestures* (the effective gestures used to play an instrument) and *ancillary gestures*, which support instrumental gestures but are not directly related to the production of sound [8]. More recently, Jensenius et al. [9] present a clear overview of the term gesture and its use in music research. They denote that the notion of gesture somehow blurs the distinction between movement and meaning as it points both to physical displacement in space and mental activation of an experience. Four functional categories of musical gestures are identified: *sound-producing* gestures, *sound-facilitating* gestures, *sound-accompanying* gestures and *communicative* gestures. This terminology and categorisation is useful to differentiate subtle aspects of musical gestures while maintaining the broader sense behind the term. The concept of *gesture* has, in fact, the considerable advantage of working as a bridge between movement and meaning, consequently bypassing the boundary between physical world and mental experiences [9]. This *monistic* [10] quality of gestures clearly makes them a key concept of the embodied music cognition paradigm as they allow the listener to relate physical aspects of movement in space to expressive qualities, in-

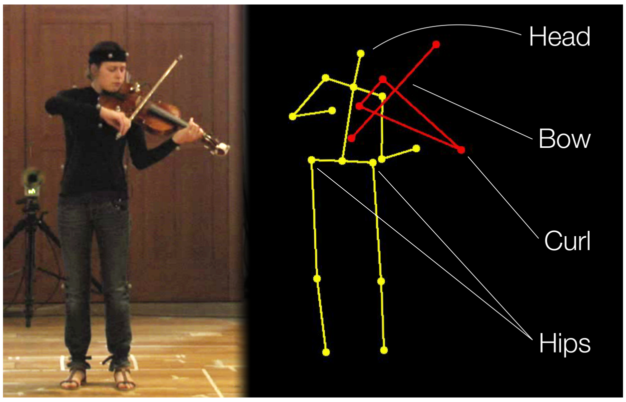

Figure 1. Multimodal recording: still from the video stream (left) and skeleton generated from the MoCap data (right).

tentions and inner feelings.

The study of musical gestures and embodied music cognition also brought about a new understanding of the relationship between musician and musical instrument. From this perspective, the musical instrument is *embodied in the body of the performer* [11] and becomes a natural extension of the musician [12]. It is therefore part of the mediation together with the body, thus allowing a spontaneous corporeal articulation of the music, contributing to the formation and conveyance of embodied musical meaning. In fact, according to Godøy [13], people continuously re-enact mental simulations of musical gestures when listening attentively to music, adding a motor-mimetic element in music perception and cognition.

With this theoretical framework in mind, it is clear that instrumentalist's gestures have considerable expressive potential. Gesture has been employed as an expressive element in musical practice across different genres and styles and has also inspired the development of several digital musical instruments [14]. To mention some applications, the composer Roberto Doati has written a series of pieces for guitar that make use of the gestures of the fretting hand of the performer to control parameters of live electronics [15]. Maes et al. [16] use the EMC theory to inform a different approach to parameter mapping and develop a human-computer interface that facilitates gestural control over real-time digital signal processing of the singing voice. Camurri et al. [17] instead employ a similar theoretical framework to implement interactive artistic applications and understand expressiveness in gestures using computational modelling.

2. AN EXPLORATORY EXPERIMENT: VIOLA BOW STROKES

In this study, a viola player is asked to perform two short pieces of music four times each, every time with different directions regarding length and quantity of bow strokes. Our intent is to observe how the variation of a musical feature also affects the movement of the performer and, secondly, if there are correlations in the way sound-producing gestures and ancillary gestures vary according to the different bow stroke styles.

Figure 2. Baroque tune: excerpt from *Pièces de violes, Livre I* (1686) by M. Marais.

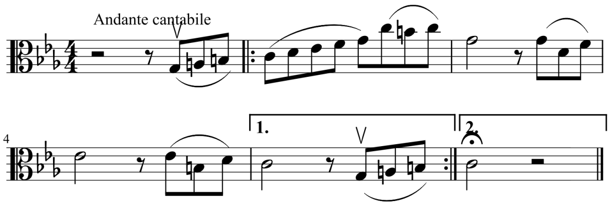

Figure 3. Romantic tune: excerpt from *Barcarolle*, from *The Seasons* (1876) by P. I. Tchaikovsky.

Past studies have observed gestures and movements of string instrument players, focusing on motion features of different bow strokes [18], the physical interaction between the player and the instrument [19] and expressivity and interaction in ensemble playing [20]. Similar studies have been carried out for other musical instruments, such as piano [21], harp [22] and clarinet [23].

2.1 Pieces and bow stroke variations

Two excerpts of two different pieces were chosen: a sarabande from *Pièces de violes, Livre I* (1686) by Marin Marais (Fig. 2) and a passage from Tchaikovsky's *Barcarolle*, from *The Seasons* (1876, Fig. 3). These pieces were chosen to allow comparison of body movements between two different styles (baroque and romantic respectively).

The viola player was asked to perform each piece in four different versions:

- as she would normally interpret it according to the score (this variation was labelled **'Natural'** in graphs for short);
- using the full length of the bow, from tip to frog, during each bow stroke (labelled **'Long'**);
- using only the central part of the bow (about one third of the total length, labelled **'Short'**);
- by performing a bow stroke for every note, therefore increasing the total amount of bow strokes necessary to perform the piece (labelled **'Many'**).

2.2 Equipment and setup

The recording took place in an auditorium/concert hall, suitable for experiments in an ecological setting. The musician performed on a stage where a multimodal recording platform was set up to capture and analyse the movement data. The data was recorded using a Qualisys Motion Capture system. The viola player wore a suit equipped with 19 reflective markers: 3 on the head, 4 on the shoulders, 1 on the back, 1 on the sternum, 2 on the elbows, 2 on the wrists, 2 on the hips, 2 on the knees and 2 on the ankles. Additionally, 3 reflective markers were placed on the viola, 2 on the body and 1 on the curl. Markers were also placed on the frog and the tip of the bow. Overall, 24 markers were used. Along with the MoCap, video and audio were recorded by means of a digital videocamera and a piezoelectric microphone placed on the viola. The multimodal stream of data was recorded and synchronised using EyesWeb XMI software platform [1] .

3. DATA ANALYSIS AND RESULTS

3.1 Movement feature extraction

In order to extract various kinematic features, the MATLAB Motion Capture Toolbox was used [24]. First, the data was trimmed to the duration of each performance. To simplify the movement analysis, the MoCap data was restructured. This was done using joints, also called secondary markers, obtained by averaging the locations of a subset of markers. Of the initial 24 markers, 4 joints (head, hips, curl and bow) were taken into account. This particular choice allows for comparison between instrumental sound-producing gestures (bow) and ancillary sound-facilitating gestures (head, hips, curl). The joint of the curl consisted of only one marker. The head joint was calculated from the three head markers, the hips from the two markers on the left and right hip and the bow from the markers at the tip and the frog (Fig. 1). Subsequently, two movement features were extracted from the joint location data:

1. Velocity for head, hips, curl and bow was calculated in order to measure the activity of the different body parts. The instantaneous velocity was averaged for each joint, in order to obtain a general value for the eight different performances.

2. The cumulative distance travelled by each joint was taken into account to measure the quantity of movement (QoM). This gives a good indication of the total amount of movement of each body part over the whole performance [25].

3.2 Results

Velocity and quantity of motion of the bow joint indicate the most immediate outcome that the bow strokes variations had for both pieces (Fig. 4, 5). In the 'Romantic' piece performance, bow velocity and QoM were much lower for the short bowing condition. In the 'Baroque' piece, the long bowing condition stands out more. In general, the bow is the most active of the four body joints for each piece in each performance, followed by the curl of the viola (Fig. 6, 7).

[1] http://www.infomus.org/eyesweb_eng.php

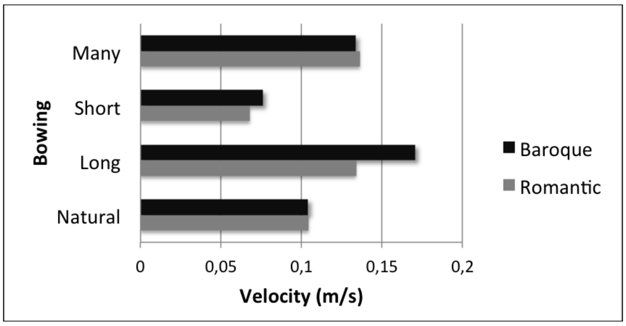

Figure 4. Velocity of the bow joint.

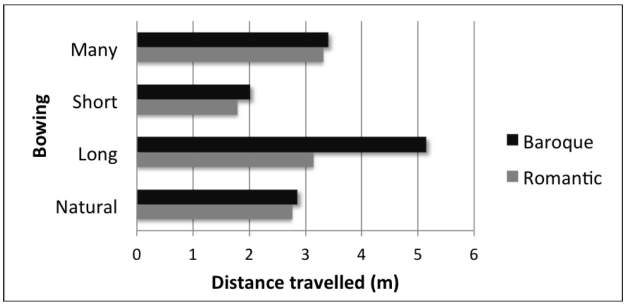

Figure 5. Quantity of Motion of the bow joint.

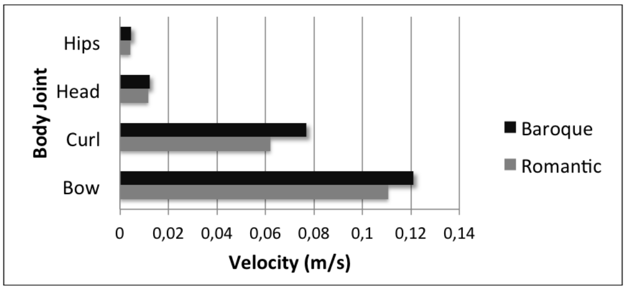

Figure 6. General velocity for the four joints in analysis.

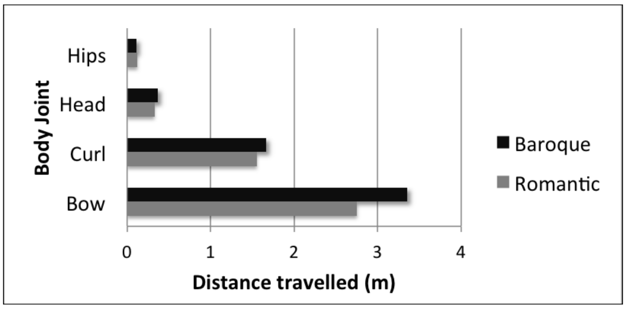

Figure 7. General Quantity of Motion for the four joints in analysis.

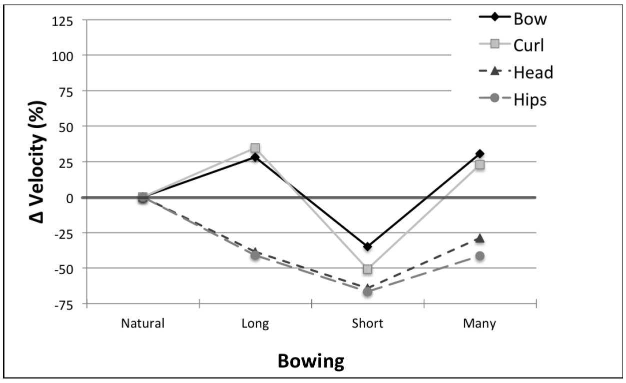

Figure 8. Differences in velocities of the ‘Romantic’ piece.

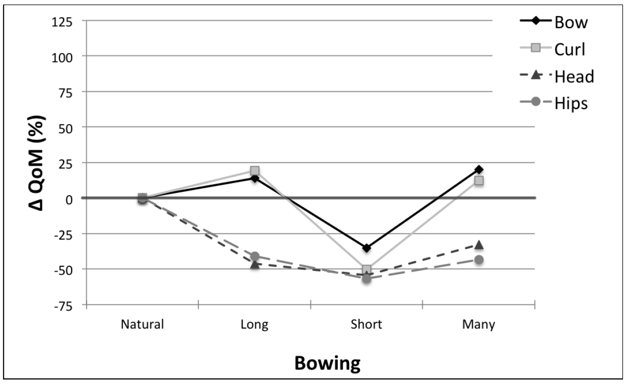

Figure 9. Differences in Quantity of Motion of the ‘Romantic’ piece.

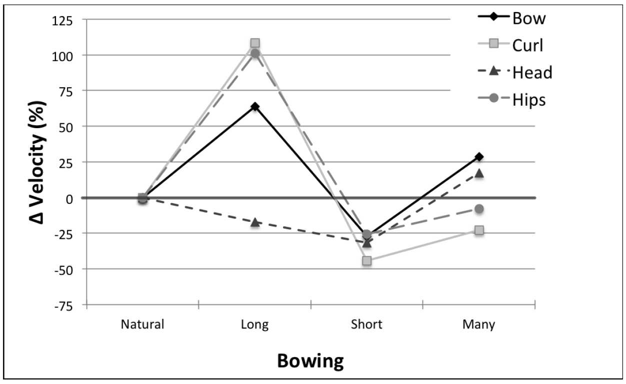

Figure 10. Differences in velocities of the ‘Baroque’ piece.

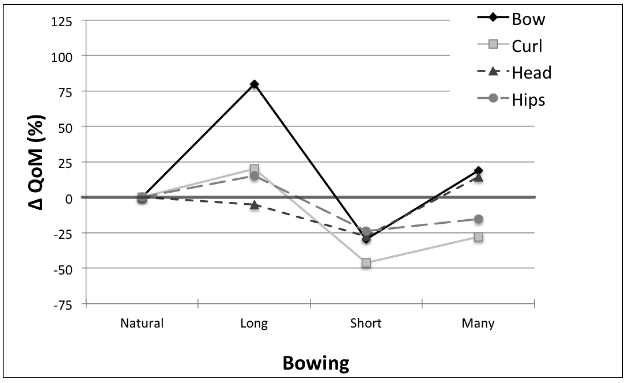

Figure 11. Differences in Quantity of Motion of the ‘Baroque’ piece.

Since the variations only involved instructions about bowing, changes of velocity and quantity of motion in other body parts are not directly induced by the task. For each joint, the velocity and QoM of the ‘Natural’ bowing performance were taken as a reference (0%) to compare against the values obtained in the other variations.

The velocity and QoM graphs of the ‘Romantic’ piece performance (Fig. 8, 9) appear similar, showing analogous ratios among the four different performances. The movement and activity induced in the curl are very similar to that in the bow, and give even larger extremes in the long and short bowing performance. A different trend is observed for head and hips. First of all, their overall velocity and QoM in general is much lower than that of curl and bow (Fig. 6, 7). As opposed to the curl, the head and hips do not increase in QoM and velocity when longer bow movements are used. For short bow movements, the head and hips are more consistent with the curl as their QoM is reduced by a half and their velocity decreases even more. Overall, head and hips are active the most in the ‘Natural’ performance variation.

The outcomes for the ‘Baroque’ piece differ to a certain extent from the ‘Romantic’ ones. Here, velocity and QoM do not change equally across the different variations (Fig. 10, 11). The QoM for the curl increases when longer bow strokes are used, but not as much as the value for the bow joint. On the contrary, the velocity of the curl more than doubles in the ‘Long’ bowing condition, as compared to the ‘Natural’ condition. When short bow strokes are used, both QoM and velocity of the curl decrease, but not as much as in the performance of the ‘Romantic’ piece. The head joint in the ‘Baroque’ performances follows a similar trend as in the ‘Romantic’ piece: its velocity and QoM do not increase with longer bow strokes and decrease even more in the ‘Short’ bowing condition. On the contrary, the hips do not follow the head movement this time. Similarly to the curl, its QoM increases with long bow strokes and its velocity doubles, while in the ‘Short’ bowing condition it decreases again.

When many bow strokes are used, another difference between the ‘Romantic’ and ‘Baroque’ piece can be observed. There is an increased effect on the head in the latter whilst the curl is more affected in the former. Moreover, many bow strokes induce almost as much movement and velocity as longer bow strokes in the performance of the ‘Romantic’ piece, which is not the case for the ‘Baroque’ piece, where longer bow strokes induce much more movement in other body parts as well. In contrast, the velocity and QoM of head and hips in the ‘Romantic’ piece are reduced to less than a half in the ‘Short’ bowing variation.

In general, short bow strokes induce the least movement and activity in all the body parts and long bow strokes induce the most QoM and velocity in bow and curl. When many bow strokes are used, only the activity and movement of the bow is consistently increased in both pieces, compared to the natural performance.

4. CONCLUSION AND FUTURE WORK

The movement data shows that ancillary and instrumental gestures may shift in analogous ways across the different bow stroke variations, but may also diverge. Similar effects of different bow strokes are found both in the 'Romantic' and the 'Baroque' pieces. Nevertheless, some variations occur, especially in the 'Long' and 'Short' bowing conditions. This is partially due to the musical structure and conventional musical style of both pieces. A sarabande is a Baroque dance, which is usually performed with shorter and lighter bow strokes to give the piece a dancing character. In the 'Romantic' piece, the performance guideline *andante cantabile* requires more bowing and vibrato to create the intended sound effect. Moreover, when comparing the original scores of both pieces, we see that in the 'Romantic' piece there are more notes per slur than in the Baroque sarabande, which implies the use of more bow in the former, and less in the latter. This explains why using short bow strokes in the 'Romantic' piece has more effect on curl and bow than using long ones and the other way around for the 'Baroque' piece.

What happens with the head and the hips is more ambiguous. As the QoM and velocity increase in the 'Long' and 'Many' bowing condition, the movements made by head and hips are reduced in comparison with the natural performance. A possible cause for this effect could be the constraints posed by the task. By adding supplementary directions regarding bow strokes, the performer focuses on the additional movements required in order to accomplish the task, which may reduce spontaneous movement in other body parts. However, a different effect is observed in the performances of the 'Baroque' piece. Here, the velocity and QoM of the hips increase when the performer uses long bow strokes, and the same can be observed in the head joint when many bow strokes are used. Again, the difference in musical style and structure could partially explain these contradictions. The long bowing condition implies more changes in the movements required to perform the 'Baroque' piece as compared to the 'Romantic' piece. Even with the task constraints in mind, these changes could affect the movements of the hips too. Still, this does not explain why this effect does not occur in the movements of the head when long bow strokes are used. Moreover, there is increased head movement in the 'Baroque' performance, but only when the performer uses many bow strokes. In this condition however, the hips seem unaffected. A study by Glowinski et al. [26] shows similar results. Three violinist performed a piece in metronomic, emphatic and concert-like styles and movements of head, torso, forearms, hips and violin were measured. Here, the movement amplitude of the hips was significantly different from the other body parts. The differences between upper and lower body parts were interpreted as part of a compensation process in which the lower body is seen as an anchoring point to enhance stability and compensate for the higher movement activity of the upper body.

Overall, it is interesting to note that increasing QoM and velocity of instrumental gestures resonate into ancillary gestures of the rest of the body in different ways and that this resonance may be hindered if the difficulty of the task increases. Different musical styles may also have an effect on how movement changes across the different bow stroke variations. It is important to note that variating the bow strokes alters the musical outcome in terms of timing, timbre and loudness of the notes. However the main goal of the experiment is to observe the results in terms of body movements and underline that variating bow articulations in the score alters not only the sound but also the corporeal expressivity of the performer, therefore affecting the experience of the performer and the audience on multiple levels, as outlined in section 1 of this paper.

Future work may go towards a more detailed analysis of other motion features and the evaluation of correspondences with recorded sound and specific passages in the score. Velocity, along with its derivatives, acceleration and jerk (i.e. acceleration variations), may be analysed over time in synchronicity with audio in order to observe note onsets and other structural features – such as beginning and end of phrases – that shape musical meaning. In addition, statistical analysis between the different performances in terms of velocity, quantity of motion and note duration may give further insights about the relationship between body movement and audible features of the performance. Joint investigation of sound and gesture articulation with acoustic instrument may also help to inform new gesture-sound mapping strategies in electroacoustic music as described by Rasamimanana et al. [27].

On a broader perspective, the purpose behind this study was to approach possible ways in which movement and gesture can be employed as an expressive musical feature, wether directly determined in the score or indirectly induced by variating other musical features. It is still not clear how gesture can be fully integrated with other expressive features in composition and performance therefore further research-led practice may lead to new helpful understandings. Moreover, movement in music performance is highly idiosyncratic; it depends on anatomical differences between players [28] and their different approaches to the instrument [22]. This preliminary work involved only one performer, so different playing styles among different performers could not be compared and statistical testing is clearly beyond the scope of this exploratory study. However, consistency with other studies [26] could be observed and the adopted methodology and the focus on the relation between pre-determined variations of musical features and resulting variations of body movement may inspire further practice-led research. In the future, gestural idiosyncrasies may constitute new interesting challenges for composers, leading them to work closely with performers in order to examine relationships between scored musical features and gestures to explore the expressive possibilities of writing more *gesture-aware* music.

Acknowledgments

This project has been carried out during the ISSSM 2014 –

International School on Systematic Musicology and Sound and Music Computing (Erasmus Intensive Programme) held at Casa Paganini – InfoMus Research Centre – DIBRIS, University of Genoa, Italy on 9-20 March 2014. We would like to thank the people at Casa Paganini – InfoMus for helping us to develop our project and setting up the multimodal recordings with great expertise and patience. We would also like to thank Marc Thompson, Jaime Del Val, Rolf Inge Godøy, Micheline Lesaffre and Antonio Camurri for their precious support and guidance, Claudia Stirnat and Liubou Pazniakova for taking part in the project and Andrew Telichan and Joran Six for their insights and thoughts during two weeks of intensive work.

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