Exploring the influence of cellists' postural movements on musical expressivity

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Abstract

In this paper we present the first part of a study on the influence of ancillary gestures, in particular postural movements, on musical expressivity in the case of the cello. Eight professional cellists were asked to play a score while their movements were recorded by a force platform (on which they were seated) and a 3D motion capture system for joint kinematics. Four playing conditions were tested: one 'normal' condition where the musicians played without any constraints, one 'mentally static' condition where they were asked to move as little as possible, and two physically constrained conditions where they were attached to the chair by a 5-point race harness. In the second physically constrained condition the musicians also had a neck collar to limit their head movements. We present here preliminary results on the influence of postural movements on the center of pressure (COP) recorded by the force platform and on some acoustical features linked to musical expressivity. These results revealed that postural constraints reorient the musicians' displacement in the medio-lateral plane and have a certain influence on rhythm, dynamics and timbre of the produced sounds.

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Background

Studies in embodied music cognition have shown that musical expression and body movements are inextricably connected (Toiviainen, Luck, & Thompson, 2010). Some studies investigated links between audio features and the musical score (De Poli, Rodà, & Vidolin, 1998), or the player (Chudy & Dixon, 2010). Others investigated relationships between musicians' expressive intentions and sound-producing gestures (Winold & Thelen, 1994). The influence of ancillary gestures (*i.e.* gestures that are not directly involved in sound production) on musicians' expressive intentions has been investigated in the case of the clarinet (Wanderley, Vines, Middleton, McKay, & Hatch, 2005; Desmet *et al.* 2012), and the piano (Thompson & Luck, 2011). Our study extends this research to a context of professional cellists.

Aims

This study presents preliminary results of a large experiment investigating the influence of professional cellists' postural displacements on their musical expressivity. A multi-modal environment combining a force platform, motion-capture, and audio recordings was used for this purpose.

We describe here the influence of the immobilization conditions on a global postural measure represented by the center of pressure (COP) of the system {cellist-cello} measured by the force platform, and on certain acoustic descriptors relevant for musical expressivity.

Method

Participants

Eight professional cellists (4 males, 4 females) were invited and paid to participate in the experiment. This paper will focus on the results obtained with one of the female cellists.

Scores

We designed a special expressive score as a combination of short studies and excerpts from *Bach* cello suites. The score contained 6 parts of specific difficulties for cello playing. We will focus on 2 parts corresponding to fast-syncopated shiftings of the left hand (part 4) and large cross-string legatos of the right hand (part 5).

Apparatus

A force platform of type AMTI (model SGA34CE) recorded the positions of COP (Center Of Pressure) for the system {cellist-instrument}, at a frame rate of 250 Hz. A 3D eight-camera optical motion capture system (Vicon) was used to record the cellists' gestures, although these Mocap data will not be discussed here. Audio data were recorded at a 44.1 kHz sampling rate via a MOTU interface (model Ultralite MIC3) from a DPA 4096 microphone placed under the cello bridge. A neck collar and a 5-point safety racing harness attached to the chair were used to constrain musicians' postural displacements without limiting their shoulder movements.

Procedure

The experiment was divided into four sessions, corresponding to the postural constraints: 'normal' (N), 'mentally static' (STH), 'static chest' (SC) and 'static chest and head' (SCH). For each session the musicians were asked to play as expressively as possible in legato or detached modes with two different tempi. Each situation was repeated three times.

COP Analysis

The computed COP positions correspond to the platform projection of a gravity center for the system {cellist-cello}. Three relevant descriptors of global postural behavior were extracted from a COP confidence ellipse containing the COP trajectories: area, principal orientation and flatness.

• The area of the ellipse is an estimation of the total surface covered by COP displacements (95% of the displacements)

• The main orientation of the ellipse is determined by the first component of a principal regression analysis applied on the COP.

• The flatness of the ellipse is obtained from its eccentricity, a measure based on the ratio between its semi-minor and semi-major axes. Main orientation and eccentricity define the antero-posterior (forward/ backward) or medio-lateral (left/right) displacement nature.

Audio analysis

To investigate the musical expressivity induced by postural conditions, three audio features were computed:

• Rhythmic deviations are extracted as each note's Interonset Interval (IOI) deviation from its theoretical (score-based) duration.

• Dynamic variations are obtained from the average Root Mean Square (RMS) value on the whole duration of each note.

• Timbral changes are estimated from the average Harmonic Spectral Centroid (HSC) value on the whole duration of each note.

Results

Influence of postural constraints on the COP descriptors

Examination of the COP ellipse descriptors (Figure 1) reveals differences in the two physically constrained conditions. Curiously, even though postural displacements are forced laterally in both cases, the ellipse expands over a much smaller area with greater flatness when the constraint is applied to the torso only (SC condition). This suggests that the subject compensates the chest constraint with her head, reducing the global COP displacement on the platform. Indeed, when both head and torso are blocked (SCH condition), the COP ellipse is simply reoriented laterally while its area and flatness are unchanged. This tends to show that the corporal coordination between torso and head constitutes an essential part of the global displacements of the cellist.

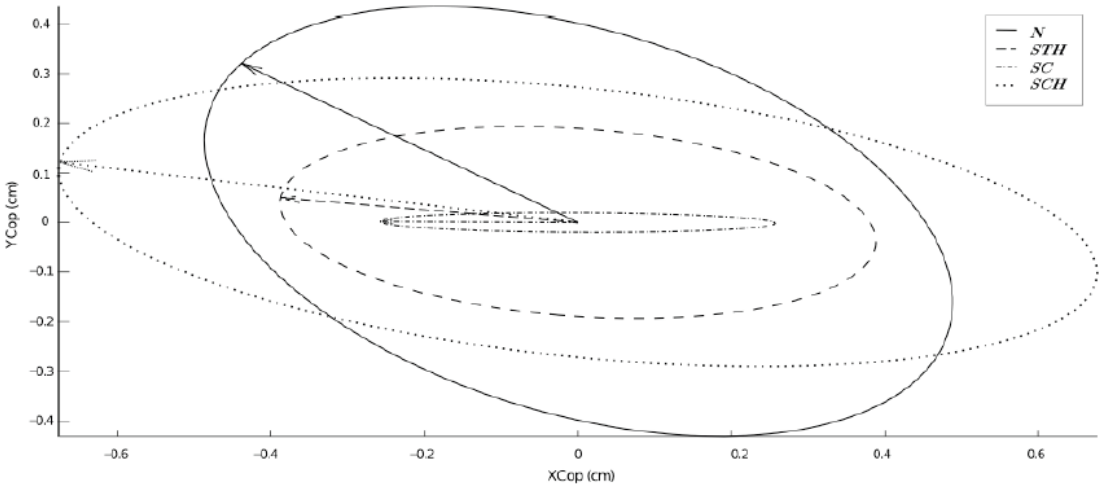

Figure 1. Geometrical features of mean COP ellipses for each postural condition (the arrow indicates the main ellipse orientation)

Influence of postural constraints on audio descriptors

The rhythmic descriptor (IOI deviations) was particularly relevant for large cross-string legatos on series of four arpeggio notes (part 5). The analysis (Figure 2) revealed that the first notes of each arpeggio were significatively lengthened when both torso and head movements are constrained (SCH condition). This result is less systematic for other static conditions (SC-STH) and tends to show that the cellist's head movements are important to ensure a global expressive coherence in the rhythmical variations.

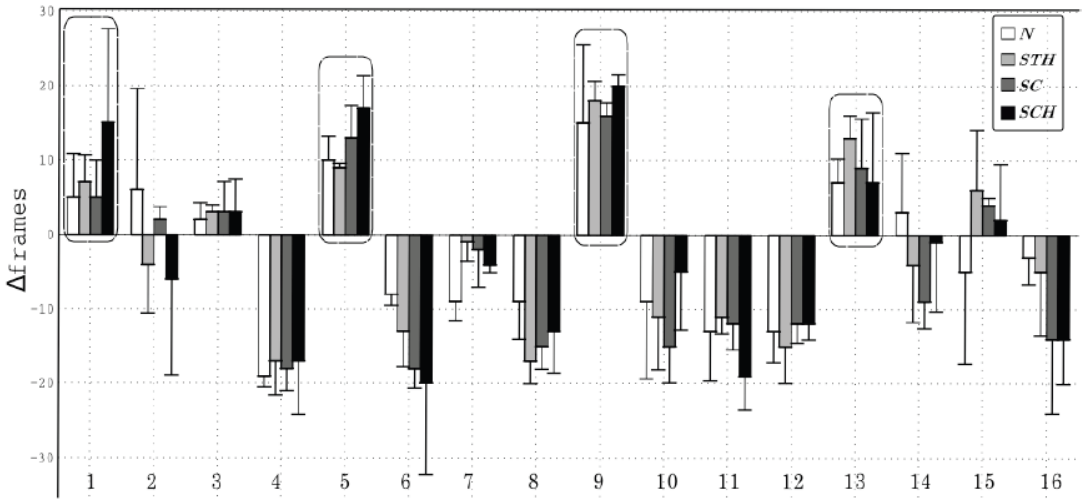

Figure 2. Mean IOI deviations on each note of part 5 and for each postural condition. Positive deviations correspond to lengthened notes, negatives deviations to shortened ones.

Analysis of the dynamic descriptor (RMS) was also relevant for large cross-string legatos (Figure 3) and revealed a quasi-systematic decrease in amplitude for the two physically constrained postural conditions (SC-SCH). The difference is particularly remarkable between normal (N) and fully constrained (SCH) situations, which tends to show that both torso and head movements are important to ensure sufficient dynamic expressivity.

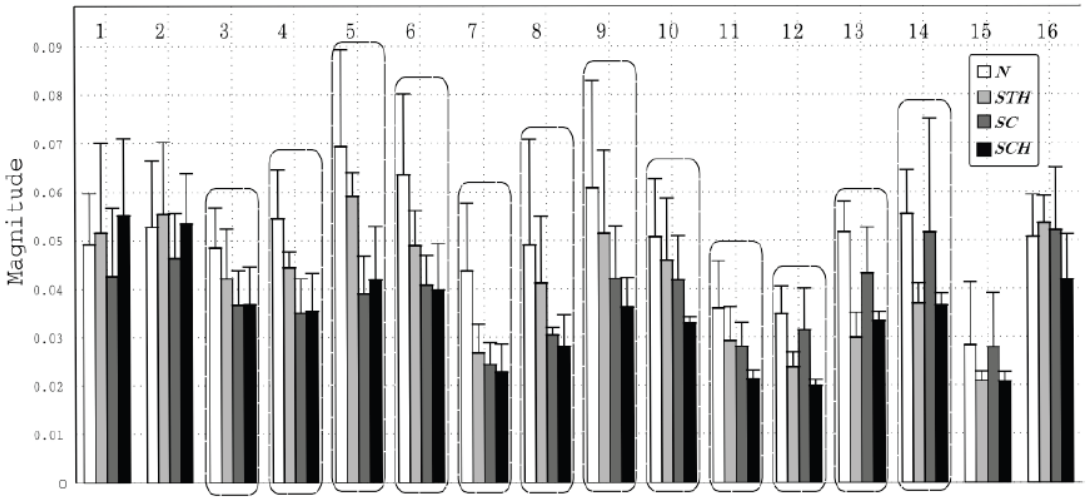

Figure 3: Mean RMS values on each note of part 5 and for each postural condition.

The timbre (brightness) descriptor revealed specific variations in part 4 (fast-syncopated shiftings of the left hand), with centroid values especially increasing on the notes preceding shifts in static postural conditions (Figure 4). This phenomenon is particularly noticeable in the fully constrained (SCH) condition, and when the fastest shiftings are executed. On the other hand, it seems less explicit in the SC condition. This result shows that head movements help the execution of fast left hand shiftings without losing the timbral quality of the sound.

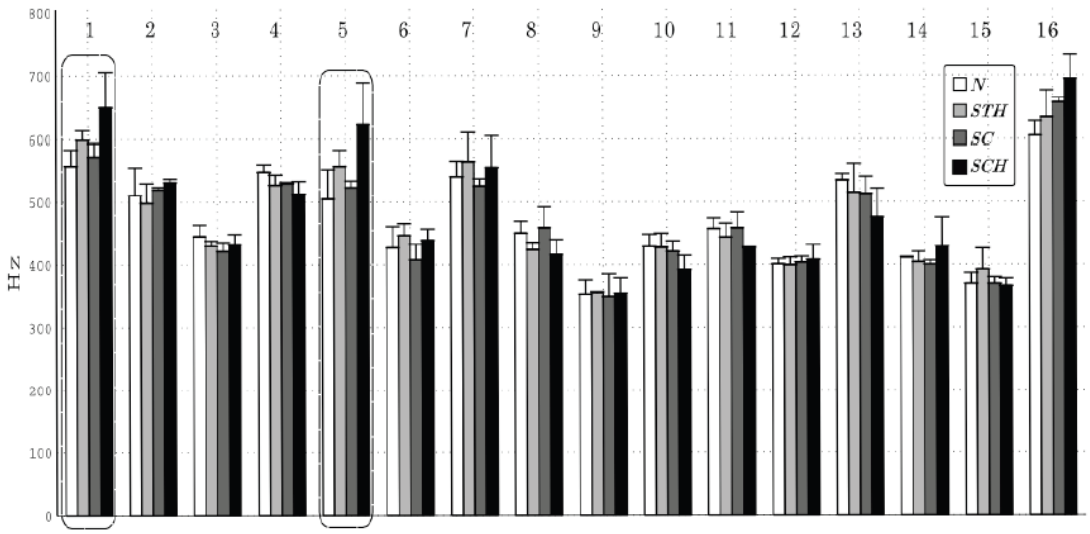

Figure 4. Mean HSC values on each note of part 4 and for each postural condition.

Conclusions

This study investigated the influence of four postural conditions on the global posture and on the musical expressivity of a professional cellist. Results stemming from the COP descriptor analysis showed that antero-posterior movements were strongly reduced by the physical immobilization, hereby validating our experiment. In addition, the use of two distinct physical constraints (torso only and torso with head) allowed us to investigate the importance of torso-head coordination on postural measures.

The influence of postural constraints on musical expressivity was analyzed through variations in rhythm, dynamics and timbre between the natural and constrained situations. Firstly, rhythmical deviations, in particular note lengthening in the completely immobilized situation, might indicate that head movements are particularly important in maintaining a global tempo. Secondly, the mean energy level, globally decreasing with increased constraint, could mean that the body movements (both torso and head) had an influence on the amplitude level of the notes. Thirdly, the brightness measure, significantly affected by the fully constrained condition in the case of fast left hand shifts, might reveal the importance of head movements in maintaining optimal timbral quality. Future investigations will include Mocap data analysis to reinforce these results and conclusions.

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