Studying the effect of creative joint action on musicians' behavior

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Abstract. How does the individual behavior of a musician change in solo Vs. creative joint action? In this paper we consider music performance, an ideal ecological test bed to investigate non-verbal social behavior, to compare the expressive movement of violinists when playing solo or in a string quartet ensemble. In the presented study, by measuring its Sample Entropy, we observe that the movement of a musician's head in creative joint action is more regular with respect to the solo condition.

Keywords: music ensemble, entropy, expressive behavior, creative joint action

1 Introduction

A very large proportion of behavioural change is induced by the social context (e.g., to perform joint action). People induce each other to move forward, or to step aside, or to retreat, by the movements they make, not on special occasions, but whenever they are doing things in the same space. That kind of influence is absolutely fundamental to human interaction and co-operation [1], but rigorous research on the topic is quite limited. Our aim in this paper is to identify a particular scenario that lends itself to rigorous research on this topic, and to introduce a hypothesis that we believe is potentially important for the area. Here and in what follows, we use 'behaviour' to exclude linguistic communication (as in the phrase 'do what I do, not what I say').

The ways in which behaviour can influence another person are very diverse, and one of the features of research on the topic is that it concentrates on some sub-areas, but leaves others relatively unstudied. Two questions tend to dominate research. One is what is being expressed, and the other is whether the message is true or misleading. That emphasis is a natural extension of research on linguistic communication, but it seems only partly appropriate when we consider how behaviour influences behaviour.

String quartets (SQs) offer a particularly promising context for investigating expressive and adaptive interactions [2,3]. Recent studies adopt music ensemble to study social interactions such as entrainment, dominance and leadership. The EU 7FP ICT-FET Project SIEMPRE (May 2010 - June 2013) has undertaken cross-disciplinary research to investigate novel paradigms and computational models of

non-verbal creative group communication adopting music scenarios (www.siempre.infomus.org).

Our approach consists in characterizing the behaviour regularity in Isolated Vs. Social context, that is, Solo Vs. Creative Joint Action performance. In the present study we focus on the distance of the musicians' head with respect to the ear of the SQ.

The ear refers to a subjective string quartet 'center', defined by the four musicians and located at nearly equal distance from each of them (see Figure 2). The ear is called such as it refers to a mental external listener that would gather the musical contributions of all the musicians. This center stands as a social reference for all musicians during the performance and helps them to coordinate and reach a coherence sound ensemble, aiming at transforming the SQ into a unique living organism. In this sense, the distance achieved from each musician's head towards the ear may reflect how each musician stands with respect to the group over the performance.

We aim at analyzing how the variation of the musician's head distance with respect to the ear is conditioned by the other musicians (e.g., effect of social context). In this context of human movement analysis, a particular measure of entropy called SampEn can be used as a method to distinguish between the two performance conditions (Solo Vs. Creative Joint Action performance) of a single musician.

2 Multimodal measures

The problem addressed in this paper is inherently multimodal: differences between solo and ensemble condition may emerge from a number of different channels, including body movement, audio signal, physiological signals (e.g., respiration, heart rate, muscles tension).

A first, general question is: which are the measures explaining the Solo Vs. Creative Joint Action performance? For this reason, we need for a number of synchronized multimodal recordings. The Synchronized Data Acquisition module in Figure 1 is in charge to do this task, and presents some non-trivial technical difficulties: the different modalities correspond to input data channels characterized by different sampling rates, ranges, and sensor systems. The acquisition task is complex: we need to obtain fully synchronized multimodal data from a motion capture system, multichannel audio signals from all the instruments (using piezoelectric microphones on the violin body) and from environmental microphones, video signals from high-quality videocameras, and physiological signals.

The synchronized multimodal recordings of the musicians obtained for this experiment as well as the details of the SIEMPRE platform for multimodal recordings are made available to the research community from the EU ICT FET SIEMPRE web pages (www.siempre.infomus.org).

In this paper, we present the results obtained so far using only the analysis of the movement of the head of the musicians, leaving to further analysis the investigation on the other channels.

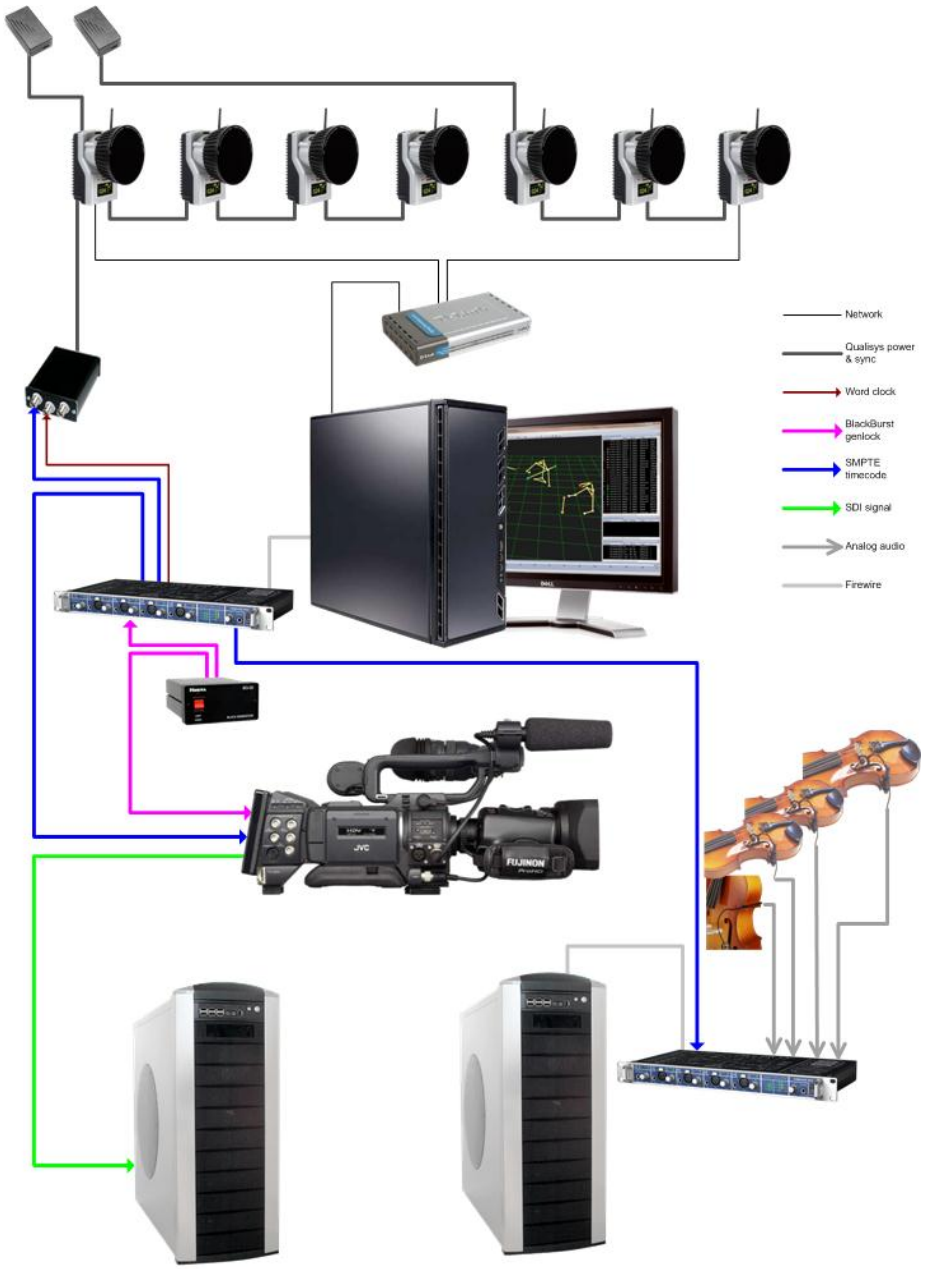

Fig. 1. The SIEMPRE software platform at the Casa Paganini – InfoMus research centre of University of Genoa for synchronized capture and recording of multimodal signals, based on our EyesWeb platform (www.eyesweb.org).

The overall scheme of the multimodal recordings platform is depicted in Figure 1.

Real-time applications have been developed in the EyesWeb XMI software platform [4], to synchronize and manage user-defined visualizations of the various channels (audio, video, motion capture, physiological data etc.).

The analysis presented in this paper concerns the time series data of the musicians' head distance to the ear of the SQ. Ongoing work in the SIEMPRE project considering the other multimodal channels are also in course. Head movement play a central role in the non-verbal communication in general [5] and in music in particular [6]. Head and upper body sway include movements, which are separate from technical or functional movements (instrumental gesture). In this sense, head movement and upper body sway are apt to express the phrasing and "breathing" of the music interpretation without being submitted to the constraints observed for other limbs such as the hands to produce the sound itself. They form shapes, embodied expressions of the models of the high-level musical structures the musician is interpreting. Head movements can also be explicit, to indicate specific moments during the performance requiring synchronized start, and may convey emotional states to facilitate interpersonal coping.

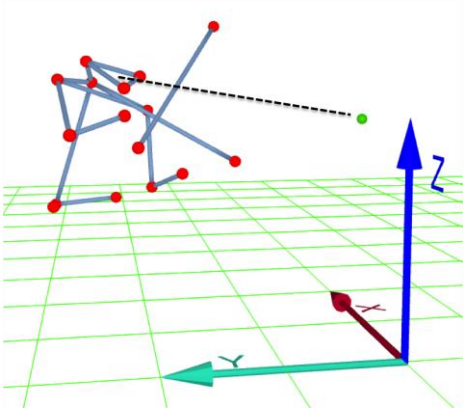

Fig. 2. Motion Capture (MoCap) data of the first violin, with particular detail of the musician's head center of gravity (COG) with respect to the *ear*, the subjective center of the string quartet (see the dashed line representing the distance between these two points)

3 Evaluation

We designed an experimental scenario to evaluate the proposed system. A multimodal setup has been created to record performances of the Quartetto di Cremona SQ. Analysis focused on the behavior of the first and second violin. Results are reported and show how musicians' head movement regularity characterizes the differences between playing solo Vs. playing in an ensemble.

The music piece performed by the SQ during the experiment was extracted from the Allegro of the String Quartet No 14 in D minor, known as Death and the Maiden, by F. Schubert. This piece is a staple of the quartet's repertoire and has been further

divided into 5 musical segments. each characterized by a prevalence of a specific musical structure.

The SQ's first and second violinists were asked to play their part 6 times alone, and 5 times with the group. Five repetitions of the same 2 minutes length music segment without any break has been considered a tradeoff between the quality of the performance and the minimum amount of quantitative data necessary to ensure significant statistical analysis. Musicians were instructed to play at best, in a concert like situation. To disentangle possible effect of group performance on solo performance, first and second violinists had to perform 3 trials before and 3 trials after the group performance. The quality of each performance was assessed by musicians through post-performance ratings (e.g., level of satisfaction, expressivity, group cohesion). Extraneous factors such as personality and emotion that may contribute to one's sensitivity of being in a group were also assessed through a BFI questionnaire and through PANAS questionnaires submitted before and after each recording session [7,8].

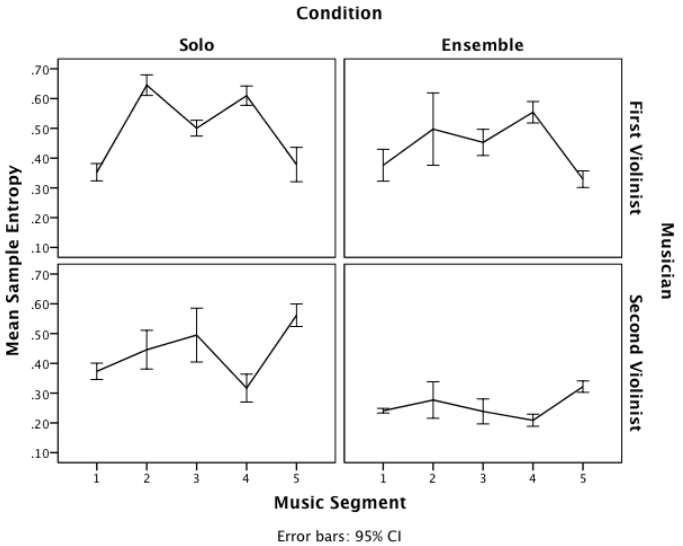

Fig. 3. Interaction plot of Condition, Musician and Music Segment on Sample Entropy.

Empirical evidence, reported in Figure 3, shows that SampEn values of musician head distance with respect to the string quartet's ear can account for the difference between Solo Vs. Ensemble conditions. Playing with others decreases the entropy of human movement related to a point situated in space, which has a social value (the ear stands as common spatial landmark to facilitate joint action). It is thoroughly logical that someone who is part of a joint action tends to make her behavior more regular: it facilitates a global alignment of the ensemble. This result is independent from the musician and from the music segment. This result confirms recent findings by Vesper et al. 2011 [9]. The authors observed that participants, who were instructed to coordinate key presses in a two-choice reaction time task, decrease the variability of their actions in a joint context compared with the same task performed individually. A

hypothesis suggested by the authors is that reducing variability, hence increasing behavioural regularity, enables achieving better predictability.

Additional evaluation could be envisaged to assess explicitly how behaviour regularity facilitates temporal coordination in String Quartet. Recent work focusing on entrainment in small music ensemble (e.g., duet, quartet) use quantitative methods such as recurrence plot analysis to evaluate the degree of synchronization between musicians [10]. Correlation analyses between the synchronization indexes and entropy through SampEn could help in assessing whether such relationship between reducing variability and increasing coordination exists in the string quartet. Another question of interest is the following: even if the observed coordination between musicians is intentional, it is still not clear whether musicians rely on explicit knowledge of the relation between variability and coordination performance or whether they were using this strategic relation consciously. Actually, people may not plan to change their own behaviour in this specific way to enable their cofactor predicting better their upcoming actions.

4 Conclusion

The promising results obtained so far open perspectives for their consolidation and for further investigation. They also confirm the preliminary results obtained in [11], using different music fragments.

Future work includes the following: (i) to extend the analysis to other body parts (e.g., shoulders, trunk sway) and features (e.g., Motion Index); (ii) to verify is the same results are confirmed by other modalities: audio data, physiological data (EMG); (iii) to better understand the dependency between musicians' SampEn values (e.g., the more the Musician 1 decreases his entropy, the higher the entropy of the Musician 2 increases?); (iv) to compare with ratings of subjects observing the single musician (without knowing if he is playing alone or in ensemble; only video, or video plus audio).

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