Communication in Orchestra Playing as Measured with Granger Causality

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Abstract. Coordinated action between music orchestra performance, driven by a conductor, is a remarkable instance of interaction/communication. However, a rigorous testing of inter-individual coordination in an ecological scenario poses a series of technical problems. Here we recorded violinists' and conductor's movements kinematics in an ecological interactive scenario. We searched for directed influences between conductor and musicians and among musicians by using the Granger Causality method. Our results quantitatively show the dynamic pattern of communication among conductors and musicians. Interestingly, we found evidence that the aesthetic appreciation of music orchestras' performance is based on the concurrent increase of conductor-to-musicians causal influence and reduction of musician-to-musician information flow.

Keywords: communication, action coordination, joint action, neuroscience of music, music performance, movement kinematics, Granger causality, neuroaesthetic.

1 Introduction

Coordinated action is a form of interaction and it has been suggested that it may rely on sensorimotor communication among participants [1]. In fact, action coordination requires the continuous exchange of information among several individuals and the ability to read other's motor intention. Therefore, coordinated action is the accurate negotiation of our own motor output according to sensorimotor messages sent by other participants in the interaction [2-7].

In this context, music orchestras are a particularly interesting instance of sensorimotor coordination between several players and a conductor. More interestingly, ensemble music performance is also a remarkable instance of social interaction aimed at a common aesthetic goal. In fact, musicians train for years in order to acquire a non-linguistic and successful sensory-motor communication. Therefore, orchestra's collective behaviors might be a powerful model of inter-individual non-linguistic communication among highly skilled individuals.

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2 Brief Methods

Here we studied music orchestras (a violins section and a conductor) in an ecological rehearsal scenario thus excerpting no particular interference on participant's behavior. We recorded violinists' bows and conductor's baton kinematics via an unobtrusive passive infrared optical system. We searched for directed influences, and modulation thereof, among actions (acceleration profiles) of the participants without imposing any artificial constraint. Eight violinists played five musical pieces they knew and routinely rehearse (Mozart K136-1, K550-1). They played all pieces three times, with their own conductor (OWN) and another professional conductor they never played with (NEW). Directed influences between participants were computed by using the Granger Causality (GC) method [8-9].

In our experiment we explored whether conductors' kinematics were associated to a differential influence on musician's performance (driving force) and if this was able to affect inter-musicians communication (interaction strength). Furthermore, we had independent expert musicians (offline and blind to the scope of the experiment) complete a questionnaire about each audio recording. The questionnaire contained items testing several subjective scales such as their ability to follow the piece (separately for melody and rhythm), the degree of musical entrainment and emotional involvement.

3 Results and Discussions

Results of GC analyses showed that the causal influence between conductors and each player was different across conductors. The New conductor drives (greater GC strength) the orchestra in two pieces out of five - namely piece 3 and 5. Moreover, we also found that players show different pattern of driving forces within them when they play under the direction of the two conductors. Under the direction of the New conductor, each player has less influence on each other in three pieces out of five - namely piece 1, 2 and 3. Questionnaire data revealed a significant interaction between Conductor and Piece but no simple effects. The interaction was further explored with follow-up tests, revealing a difference between conductors in pieces 3 and 5.

Results show that the two conductors exhibit different driving forces strength towards musicians in some pieces, whereas communication strength among players was also modulated by the characteristics of the two conductors in others. Conductors' directed drive differed in two of the pieces (3, and 5), whereas the conductors modulated inter-musician influences in three pieces (1, 2 and 3).

However, we have to take into account that such dynamical network of causal interactions was aimed at producing a pleasurable effect in the listeners. Interestingly, aesthetic evaluations were modulated by piece and conductor. Specifically, two pieces (number 3 and 5) were considered significantly different between conductors. Interestingly enough, piece number 3 was the only one showing a differential influence of one conductor over the other in affecting players and at the same time affecting inter-musicians communication. Therefore, it might be the case that the aesthetic appreciation

of music orchestras' performance is based on the concurrent increase of conductor to musician causal influence and a reduction of musician-to-musician information flow.

In conclusion, the present results add to the growing body of research that considers musicians as a perfect model to study sensory-motor brain plasticity and organization [10]. Here, we used musicians as a model of how effective communication might be based on efficient gestures coordination. In fact, each musician is certainly reading a score, knows perfectly what to play, and can listen and see what other musician do. However, the violinist has to concurrently follow the conductor, providing critical information on how to interpret a given piece. The musician has to wisely balance several external sources of information and mix them up in order to reach the required performance.

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