International Symposium on Performance Science
ISBN 978-2-9601378-0-4

Temporal coordination in string quartet performance

Renee Timmers[1], Satoshi Endo[1], and Alan M. Wing[2]

[1] Department of Music, University of Sheffield, UK
[2] School of Psychology, University of Birmingham, UK

Temporal coordination between members of a string quartet performing an excerpt of a Haydn string quartet was characterized in terms of patterns of dependence between player note onset times estimated from acoustic data, and compared to self-reported patterns of dependence between players. Audio onsets revealed temporal dependencies indicative of a leading-following relationship between the first and second violin and a relationship of mutual adaptation between the first violin and both the viola and cello. This relationship of mutual adaptation was not reflected in the self-reported dependencies, which predominantly ascribed a leadership role to the first violin.

Keywords: timing; synchronization; string quartet; self-report; measurement

Investigations of group dynamics in chamber music ensembles have suggested the relevance of leadership as well as democracy for the successful operation of such groups (Murnighan and Conlon 1991). Within string quartets, artistic leadership is often attributed to the first violin, while other members may take up other roles, organizational or social, or may function as "deputy" leader (King 2006). The second violin may seem to have the least significant role by primarily supporting the melody; it is nevertheless essential to the success of the group, a phenomenon known as the paradox of the second violin (Mullighan and Conlon 1991).

These dynamics between ensemble members concern their musical roles and social relationships, and may be indicative of processes of decision-making. It is likely, however, that similar patterns of interaction operate during performance and influence the way in which string quartet members coordinate with each other over time.

There may be a single "leader" of an ensemble who the other members follow to assure ensemble synchronization, or synchronization may be a more reciprocal process in which timing adaptation is bidirectional across ensemble members. For duo performances, evidence for reciprocal rather than uni-directional adaptation has been found (Goebl and Palmer 2009). Evidence also exists that accurate prediction of a partner is more beneficial to temporal synchronization than leadership, with optimal results being obtained if a duo consists of two predictors (Pecenka and Keller 2011). The case may be different, however, for larger ensembles. As Rasch (1979) demonstrated, larger ensembles may need a clearly uniting point of reference, such as a conductor, for successful synchronization.

Even if ensembles have a leader who provides a primary reference for temporal coordination, it is still likely that individuals distribute attention and respond to and correct for asynchronies with other members of the ensemble. The degree of allocation of attention to timing across players is of particular interest (Keller 2001) and may vary depending on such factors as the perceptual salience of the instrument or the similarity in musical function between players.

The aim of this study was to investigate how members of a string quartet adjust their timing to each other and, in particular, to investigate patterns of uni-directional or bi-directional dependencies. We estimated timing dependencies from inter-response interval data (intervals between note onsets) and compared these with self-reported dependencies between pairs of performers in order to evaluate the usefulness of self-report in exploring synchronization strategies in string quartets.

METHOD

Participants

An existing string quartet of professional musicians participated who had played together for 5 years at the time of the study.

Materials

The musicians performed the first eight bars of the *String Quartet in G Major, Op. 77 No. 1* by Joseph Haydn (see Figure 1). This excerpt was selected because of the relatively high proportion of synchronous notes across the two lower instruments. Violin I states a simple ornamented theme, echoed by Violin II, while Viola and Cello provide steady accompanying pulses.

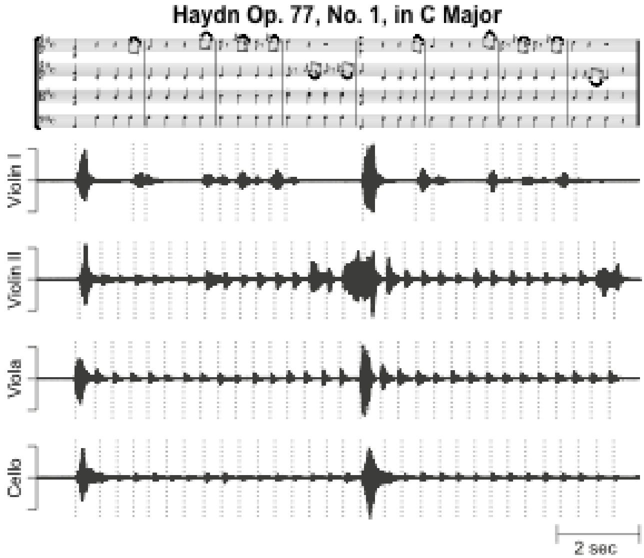

Figure 1. The excerpt and a single trial example of audio data of the quartet. The vertical dotted lines indicate the note onset detected from their respective audio signal.

Procedure

The quartet was seated in a circle of radius approximately 2 m with, from stage right to left, Violin I, Violin II, Viola, and Cello. They performed the musical excerpt 15 times, endeavoring to make each repeat an individual performance with some variation in interpretation. At the end of the block, participants indicated their subjective estimates of temporal dependencies between pairs of performers using a questionnaire: firstly, the players reported the dependence on each player including him/herself in a percentage (the sum of the score across the quartet summed to 100%). Secondly, they indicated the dependence that they expected each of the other players would report.

Audio data were recorded at 41 kHz using an omnidirectional miniature condenser microphone attached below the strings between bridge and tailpiece using a rubber clip. The audio data for each instrument were rectified and then smoothed using a bi-directional 2nd-order Butterworth low-pass filter with a cut-off frequency of 50 Hz. Local maxima of the signal, corresponding to successive notes were detected (see Figure 1), and note onsets were determined using an adaptive threshold applied to the “valley” preceding each maximum. The inter-response intervals (IRI) of note onsets were then calculated for each player.

RESULTS

The timing dependency between pairs of instruments was calculated by cross-correlating IRI variability between players after removal of changes in tempo estimated from the average of the 15 repetitions. The correlation was calculated at the bar level to allow for missing onsets due to rests in Violin I.

Figure 2 shows an overview of the correlations, including auto-correlations along the diagonal. Within each box, correlations at different lags are given from a negative to a positive lag of four positions. In case of negative lags, the voice in rows is shifted 1, 2, 3, or 4 bars backwards with respect to the voice in columns. In case of positive lags, the voice in rows is shifted forwards.

Positive cross-correlations at lag 1 indicate that the instrument of the column follows variations in IRI of the instrument in rows. This is the case for the Viola (third column) and Cello (right column) adapting to the second Violin (second row). The second Violin (second column) followed the first Violin (top row). Mutual adaptation (positive correlations at lag 1 and lag -1) can be seen between the first Violin and Cello at lag 1, and between the first Violin and the Viola at lag 2. Negative values at lag 0 support the idea of a 1st order linear correction between instruments. Interestingly, all cells have a negative coefficient at lag 0, although the coefficients are especially strong for correlations with Violin I, and for the correlation between the Cello and Violin II.

Turning from cross-correlations to autocorrelations, these were negative at lag 1, which is consistent with the Wing and Kristofferson (1973) model of internal timing control.

Figure 3 shows the self-reported dependencies between pairs of instruments. The left panel shows the indications of players of the extent to which their own timing depends on the timing of others or on themselves. The right panel shows the means of the ratings by others of the timing dependency between voices other than themselves.

The left panel shows that ratings of dependence were highest for self in the case of Violin I and II. The Viola and Cello indicated to depend in particular on Violin I and II. The right panel shows that expected ratings of dependence by other players were highest for self with the expected rating for Violin I next highest. The inter-rater reliability in terms of Pearson’s coefficient was $r=0.63$ (± 0.163).

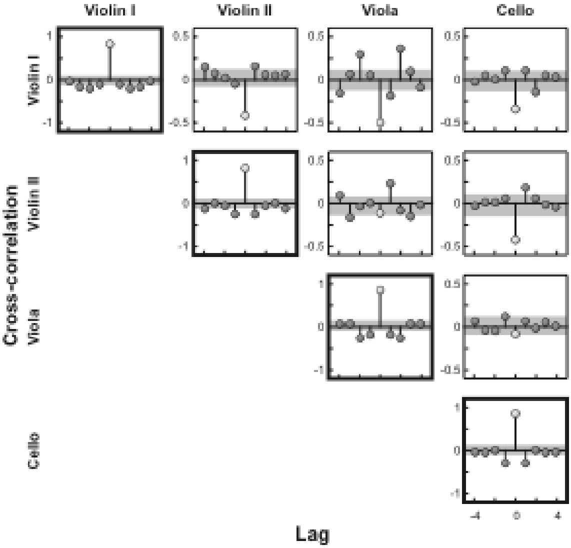

Figure 2. A matrix of cross-correlation coefficients of IRIs between players. In the diagonal axis (bold squares), the autocorrelations are shown. Shaded areas indicate one standard error.

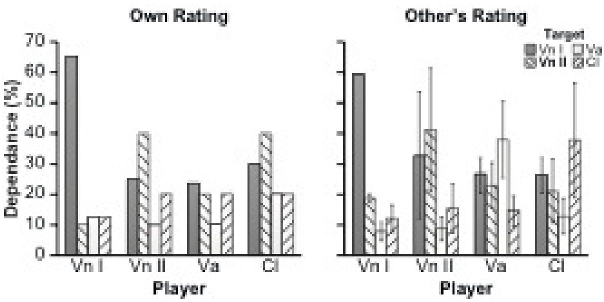

Figure 3. Subjective ratings for timing dependency of own performance and the averaged ratings by the other players. The error bar represents one standard deviation.

DISCUSSION

The measured timing dependencies (see Figure 2) suggested several leading-following relationships with Violin II following Violin I and the Viola and Cello following Violin II. Mutual adaptation was observed between Violin I and the Viola and Cello. In contrast, the expected dependence patterns (see Figure 2, right panel) emphasized the first violin as the leader. Although the data is limited and the results preliminary, the apparent discrepancy between self-report and observed timing dependence may not be a surprise. Correction of timing errors operates at a subconscious level (Repp 2001) and may not be accessible for reflection. While this may cast doubt on the usefulness of self-report in uncovering strategies of ensemble synchronization, a combination of methods may nevertheless prove most informative in uncovering explicit and implicit strategies of temporal coordination.

Address for correspondence

Renee Timmers, Department of Music, University of Sheffield, 34 Leavygreave Road, Sheffield S3 7RD, UK; *Email:* r.timmers@sheffield.ac.uk

References

Goebl W. and Palmer C. (2009). Synchronization of timing and motion among performing musicians. *Music Perception, 26,* pp. 427-438.

Keller P. E. (2001). Attentional resource allocation in musical ensemble performance. *Psychology of Music, 29*, pp. 20-38.

King E. C. (2006). The roles of student musicians in quartet rehearsals. *Psychology of Music*, *34*, pp. 262-282.

Murnighan J. K. and Conlon D. E. (1991). The dynamics of intense work groups: A study of British string quartets. *Administrative Science Quarterly, 36,* pp. 165-186.

Pecenka N. and Keller P. E. (2011). The role of temporal prediction abilities in interpersonal sensorimotor synchronization. *Experimental Brain Research*, *211*, pp. 505-515.

Repp B. H. (2001). Phase correction, phase resetting, and phase shifts after subliminal timing perturbations in sensorimotor synchronization. *Journal of Experimental Psychology: Human Perception and Performance*, *27*, pp. 600-621.

Rasch R. (1979). Synchronization in performed ensemble music. *Acustica*, *43,* pp. 121-131.

Wing A. and Kristofferson A. (1973). Response delays and the timing of discrete motor responses. *Perception and Psychophysics, 14,* pp. 5-12.