



Background

- Musicians communicate through sensorimotor information in their body sway movements, which reveal how they are going to play next.
- We have investigated nonverbal communication in musicians by measuring the body sway of classical musicians with motion capture 1,2 .
- Granger causality (GC) methods show how much information flows from one body-sway time series to the other.
- Cross-correlation (CC) methods show how similar are musicians' body sway.
- Recently in Wood et al., 2022, we demonstrated information flow decreased on average, but similarity increased in a professional string quartet that learned to play two unfamiliar pieces over eight trials³.
- We averaged these measures over the entire pieces, but the measures could be related to musical features within a single trial (e.g., phrase endings).
- Here, we examined GC and CC during particularly expressive sections of these pieces.

Study aims

As an ensemble learns to play unfamiliar pieces, how do information flow (GC) and similarity (CC) change during expressive phrase endings? Furthermore, how do these measures relate to performance quality?

To test this, we used the same motion capture dataset from Wood et al., 2022 of a professional string quartet learning two unfamiliar pieces over 8 trials and analyzed GC and CC during phrase ending sections.



- We expected that GC would decrease and CC would increase as the string quartet learns the pieces, similar to the averaged measures from Wood et al., 2022.
- We also expected 1) a negative relation between GC and performance quality ratings, and 2) a positive relation between CC and performance quality ratings.

Coordination dynamics in a professional string quartet during phrase endings

Department of Psychology, Neuroscience & Behaviour, McMaster University

Methods

Participants

Expert string players (N=5, 4 females, avg. age = 39.2 years, avg. years of experience = 34.6) were recruited to rate phrase ending clips.

Clips

- We used the existing dataset from Wood et al., 2022 of a profession string quartet learning two unfamiliar pieces (Quartett in G by Frar Berwald, String Quartet No. 1 in D major by Niels Gade) over eight subsequent trials each.
- We selected three 30-second phrase endings from each of the two pieces, characterized by expressive timing and dynamic changes (e diminuendos, fermatas, etc.), for a total of 6 clips.
- We then created a survey with the phrase ending clips to be rated the participants, for quality, expressivity and synchrony.

Measures

• We used GC to measure information flow and CC to measure similarity between the group's body sway time-series in the clips across trials.



Figure 3. Average GC, CC, and quality ratings over the eight trials. The left is piece 1 and the right is piece 2. Colour represents the three different clips selected from each piece. **A.** Average information flow (GC) of group body sway shows a decreasing trend as musicians learn the phrase endings. **B**. Average similarity (CC) measures of group body sway increase as musicians learn the phrase endings. C. Average quality ratings of the phrase endings by expert musicians increase over trials.

Alyssa Murdoch, Emily A. Wood, Andrew Chang, Dan Bosynak, Lucas Klein, Elger Baraku, Dobromir **Dotov & Laurel Trainor**

onal nz	Α	
	В	99 dim. mf dim. p
)		$\dim m f \dim p <> i i dim.$
e.g.		$\frac{10^{++}}{dim.}$
		$\begin{array}{c c c c c c c c c c c c c c c c c c c $
by		Figure 1A. Example of an expressive phrase ending chosen from piece 1, Quartet in G (Franz Berwald). This clip was selected for the rallentandos and fermatas.
		B. Example of an expressive phrase ending chosen from piece 2, Quartet No. 1 in
		D Major (Niels Gade). This clip was selected for the diminuendos and changes in
		expressive dynamics.

Results

Figure 4. The blue graphs represent correlation between information flow (GC) and quality ratings, while orange graphs represent correlation between similarity (CC) and quality ratings. No significant correlation was found between GC/CC and A. quality, B. expressivity, or C. synchrony ratings







Discussion

- Our preliminary data shows that group information flow (GC) shows a decreasing trend across trials, in line with the findings from the averaged measures over the entire piece³.
- Group similarity (CC) showed an increasing trend, also in line with the averaged measures³, indicating that musicians improve their coordination as they become more familiar with the pieces.
- There was no relation between our GC and CC measures and the ratings of performance quality provided by our raters, however, only five raters have participated, and data collection is ongoing.
- **Overall, our measure of information flow** decreased and similarity increased across trials for phrase endings, indicating that the ensembles body sways reflect their learning of a common internally based expressive interpretation

Future directions

- Data collection from raters for performance quality is ongoing.
- We are completing additional analyses of GC and CC during sections of the music where the group made mistakes to investigate how dynamic coordination changes when the group would need to communicate nonverbally

References

- Chang, A., Livingstone, S. R., Bosnyak, D. J., & Trainor, L. J. (2017). Body sway reflects leadership in joint music performance. Proc Natl Acad Sci, 114(21), E4134-E4141.
- Chang, A., Kragness, H. E., Livingstone, S. R., Bosnyak, D. J., & Trainor, L. J. (2019). Body sway reflects joint emotional expression in music ensemble performance. *Sci Rep*, *9*(1), 1–11.
- Wood, E. A., Chang, A., Bosnyak, D., Klein, L., Baraku, E., Dotov, D., & Trainor, L. J. (2022). Creating a shared musical interpretation: Changes in coordination dynamics while learning unfamiliar music together. Annals of the New York Academy of Sciences, 1516(1), 106–113. https://doi.org/10.1111/nyas.14858

