

SUMMARY

Group size and delay have significant effects on group synchrony in a virtual “rhythm network” paradigm.

INTRODUCTION

The Drum Circle as an Investigational Tool

- Drum circles provide a naturalistic setting for studying group timing and coordination
- In typical settings, everyone can hear each other, enhancing synchrony as group size increases (Dotov et al. 2022).
- We examined what happens when this information is reduced - when participants hear only selected partners or experience feedback delays.
- Building on work showing a U-shaped relationship between delay and synchrony (Koike et al. 2024), we manipulated network topology and delay to test how communication structure and timing constraints shape emergent group synchrony.

Hypotheses

1. **Network Topology:** Synchrony will increase with group size in all-sync networks but decrease in ring-sync networks.
2. **Delay:** Moderate delays (120ms) will produce the most stable synchrony (U-shaped relationship).
3. **Musical Experience:** Groups with higher average musical experience will show stronger synchrony.

METHODS

Manipulation of Network Dynamics via the Rhythm Network Topology:

- All-sync: each participant heard all others.
- Ring-sync: each participant heard only the person to their right.

Group Size:

- Groups of 6 were subdivided into duets, trios, quartets (+ duets), and sextets. Each participant group was evaluated at every group size.

Delay

- Inter—participant auditory delays of 0ms, 120ms, and 240ms were introduced through the digital audio routing system.

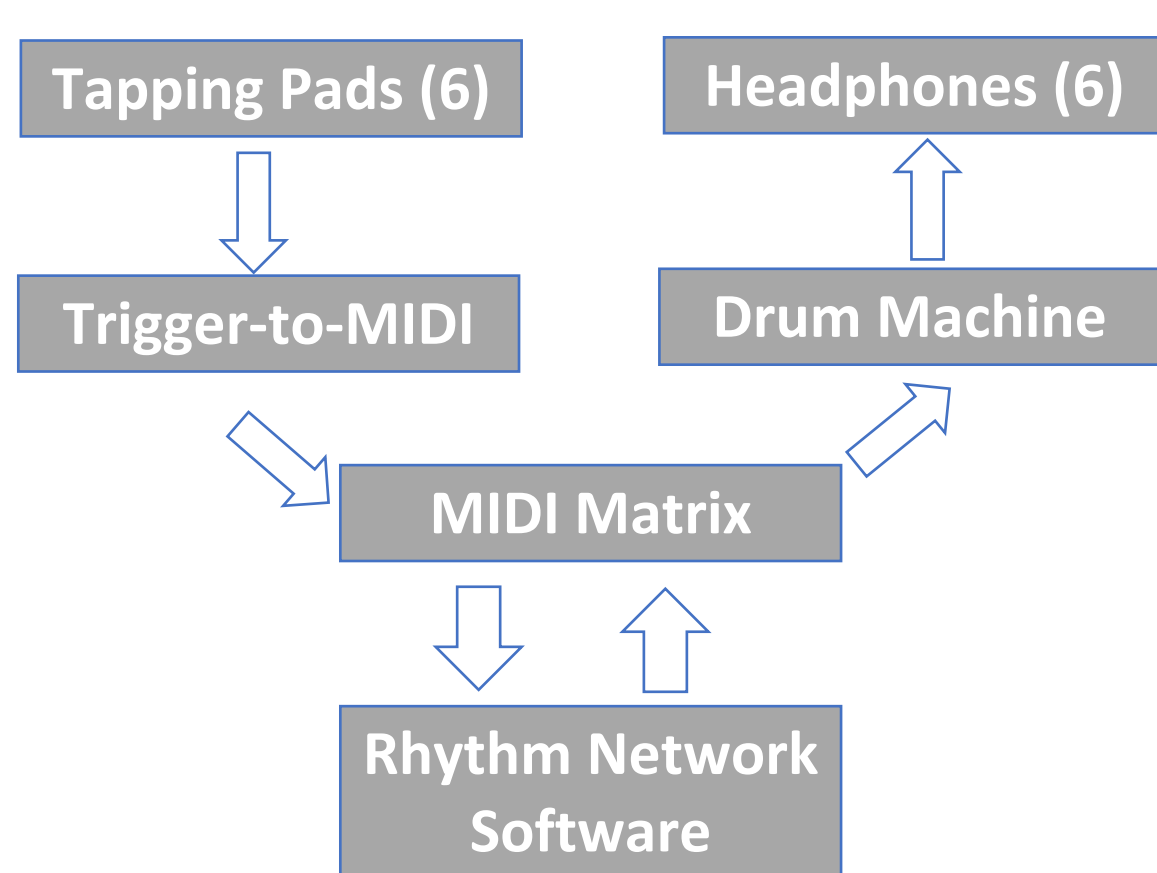


Fig 1. Basic schematic of the signal chain, from tapping pad to headphones.

MEASURES

Kuramoto Order Parameter (R)

- Group synchrony was quantified using the **Kuramoto order parameter (R)**, which measures phase alignment among participants.
- **R = 1** indicates perfect synchrony; **R = 0** indicates complete asynchrony.
- **Masking:** We applied a mask to gaps of >2000ms, e.g. when at least one participant stopped tapping.
- **Perspectives:** in delay trials, R was calculated both globally (across all participants), and individually, using each participant’s tap stream as a reference.

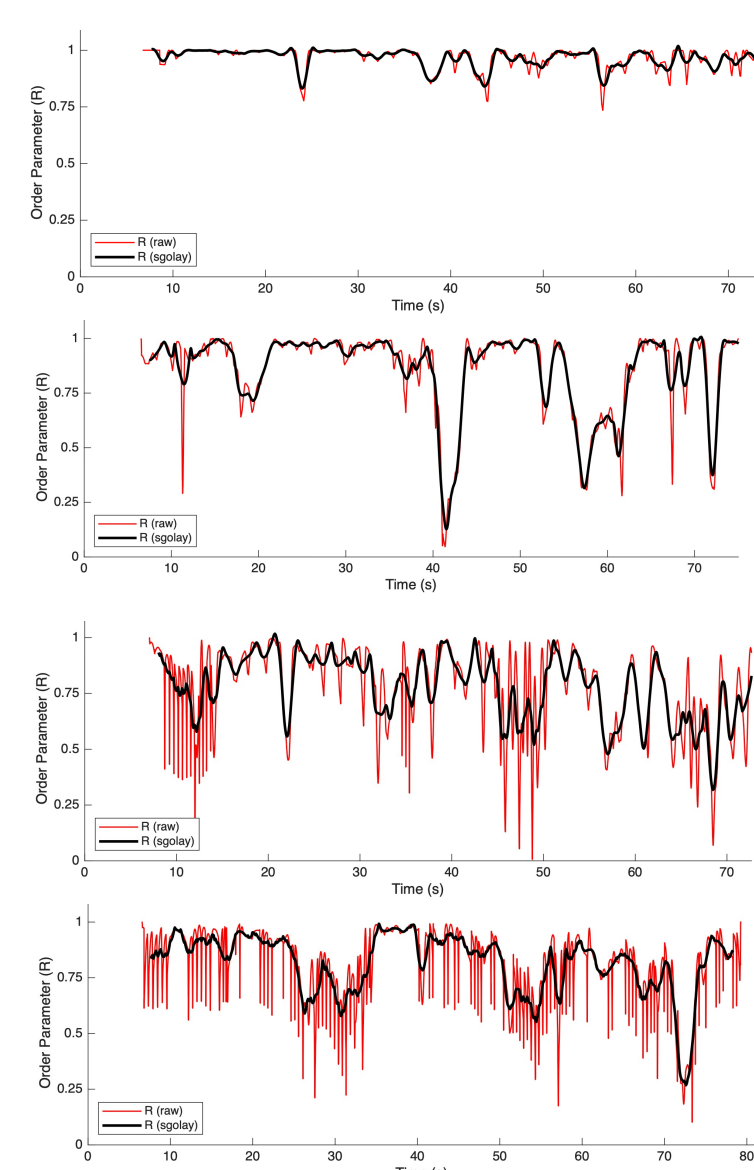


Fig 2. (from top to bottom) Kuramoto order parameter (R) over the course of a trial for a duet, trio, quartet, and sextet, respectively.

GROUP SYNCHRONY ANALYSIS

Single-Trial Data Provide Insights into Individual Strategies and Group Dynamics

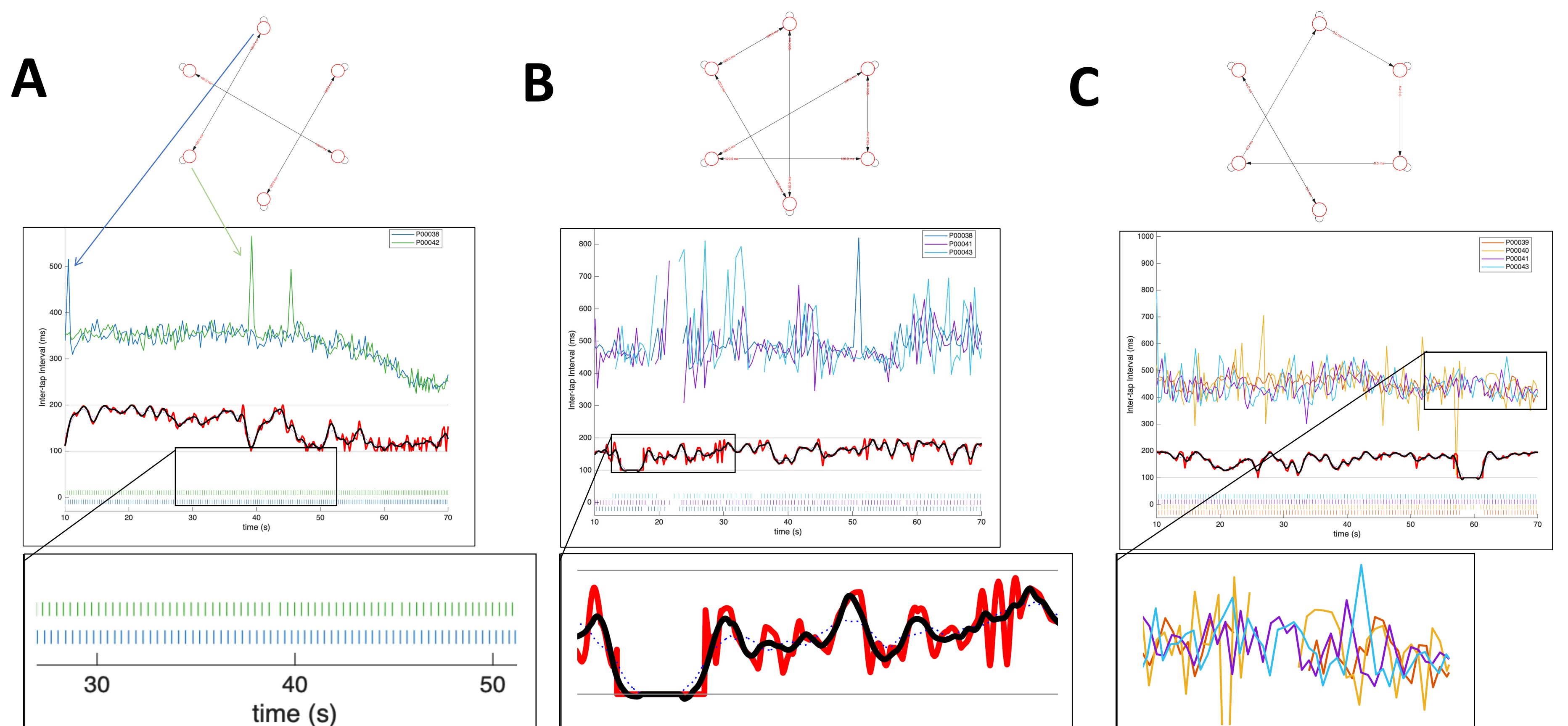


Fig 3. A) Data from a duet trial, all-sync with an inter-participant delay of 120ms. Highlights which drummers were paired (seats 1 and 5), their respective ITI curves, and an enlarged image of the tap raster. B) Data from a trio trial, all-sync with an inter-participant delay of 120ms. Shows enlarged image of the order parameter. C) Data from a quartet trial, ring-sync with a delay of 0 ms. Shows enlarged image of the ITI curves.

Group-Level Analysis Shows Linear Effect of Delay on Synchrony

Global model (no duets): Synchrony falls linearly with delay; no U-shape observed.

- Synchrony decreased with delay ($F(2,405)=68.1, p<.001$) and was higher in all-sync than ring-sync networks ($F(1,405)=35.5, p<.001$). Larger groups were slightly more stable ($p=.02$). No interactions were significant.

All-to-all (with duets): Delay disrupts coordination even in fully connected groups; larger groups magnify the effect.

- Both delay ($F(2,351)=36.2, p<.001$) and group size ($F(3,42)=7.2, p<.001$) affected synchrony.
- 0 ms > 120 ms > 240 ms for all sizes; duets plateaued after 120 ms, sextets declined most (≈ 0.33 R units).

Refchan model (delays only): Desynchronization reflects a group-level property, not an artifact of measurement.

- Main effects of topology, delay, and group size persisted (*all* $p<.05$). Between-group variation dominated; within-group (refchan) variance was minimal.

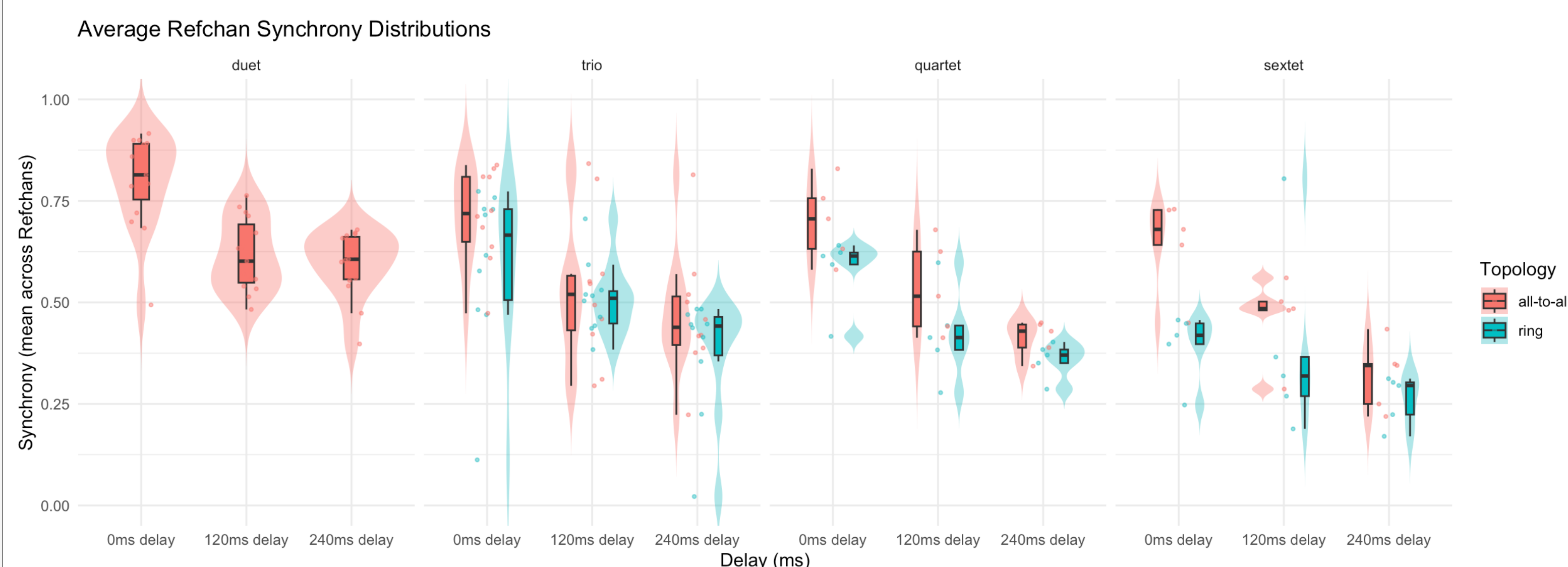


Fig 4. Violin plot of average refchan synchrony (0ms shows global synchrony only). All-sync in red, ring-sync in blue. Results categorized by group size.

MUSICAL EXPERIENCE

Investigating the role of Musical Experience in group synchrony outcomes

- We surveyed participants on their musical experience prior to their participation.
- However, none of our musical experience measures (self-reported level, years played, years played x hours/week) significantly predicted synchrony within a subgroup.

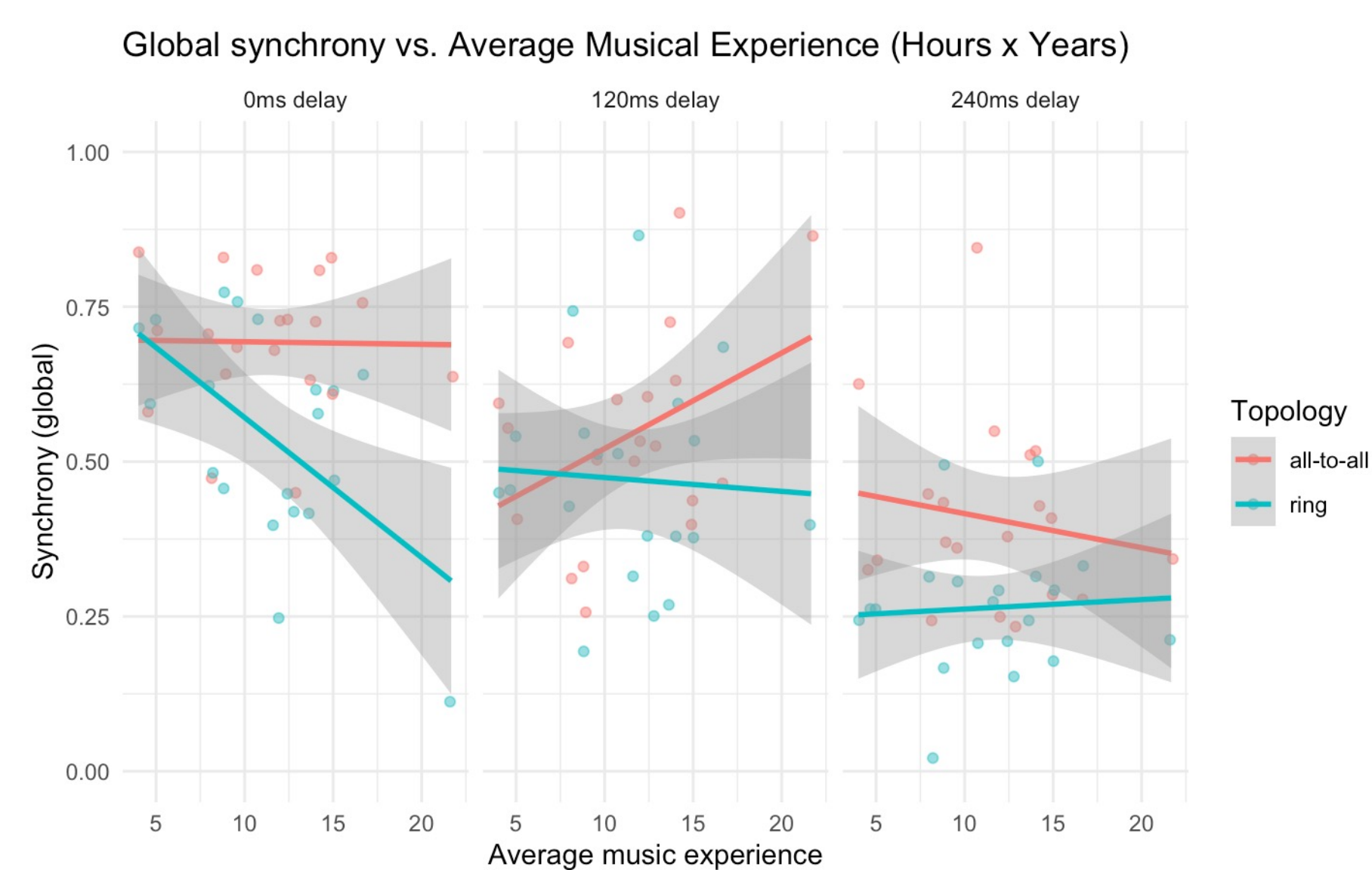


Fig 5. Synchrony for duets vs. Average Music Experience within a subgroup (years actively played x hours/week when active). Average musical experience did not predict synchrony ($F(1,32)=1.50, p=.23$).

CONCLUSIONS & FUTURE WORK

1. **Network topology:** Synchrony was consistently higher in all-sync than ring-sync, confirming that full connectivity supports stronger coordination.
2. **Delay:** Synchrony declined linearly with delay—both 120 ms and 240 ms disrupted timing, with no U-shaped recovery.
3. **Group size & musical experience:** Larger groups achieved slightly higher overall synchrony, but musical experience did not significantly predict performance.

Self-feedback may influence delay effects

- No self-feedback in previous work on delays
- Self-feedback had 0ms delay in our study
- Dissonance between self-feedback and partner taps may reduce synchrony.

Emergent synchrony vs. Sync-Continuation

- Emergent synchrony paradigms may magnify individual differences in tempo preference, leading to increased tapping variability.

Future Directions

- Does solo-tapping behavior predict performance in group contexts?
- Does self-feedback + delay disrupt synchrony?

REFERENCES

- Dotov, D., Delasanta, L., Cameron, D. J., Large, E. W., & Trainor, L. (2022). Collective dynamics in human circle drumming: The role of group size and synchronization. *eLife*, 11, e74816. <https://doi.org/10.7554/eLife.74816>
- Koike, Y., Ogata, T., Nozawa, T., & Miyake, Y. (2024). Effect of time delay on performance and timing control in dyadic rhythm coordination using finger tapping. *Scientific Reports*, 14(1). <https://doi.org/10.1038/s41598-024-68326-6>