TEAM COLLABORATION AND COMPETITION

A NOVEL, SCALABLE PARADIGM IN JOINT ACTION RESEARCH

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Source Code

Online demo

Joint action: classic paradigms

- Classic joint action paradigms[1] have revealed robust effects in dyadic interactions including the joint Simon effect,[2] SNARC effect,[3] joint memory effect,[4][5] interpersonal synchronization patterns,[6][7] and dynamics of collaboration and competition.[8][9]
- However, it is unclear as to how classic paradigms of joint action scale to larger groups.

> ***Do established coordination dynamics in dyads scale up to larger groups?***

Collaboration & competition in team-based group interaction

- Established dynamics of cooperation and competition[8][9] from dyadic research may display novel emergent features in group interactions.
- Specifically, group interaction affords the possibility for simultaneous cooperation and competition between subgroups, i.e., teams.

> ***What methods can be used to investigate how the dynamics of cooperation and competition change from dyadic to team-based interaction?***

Measuring group collaboration & competition: gaming approach

Measuring multimodal group synchrony: key challenges

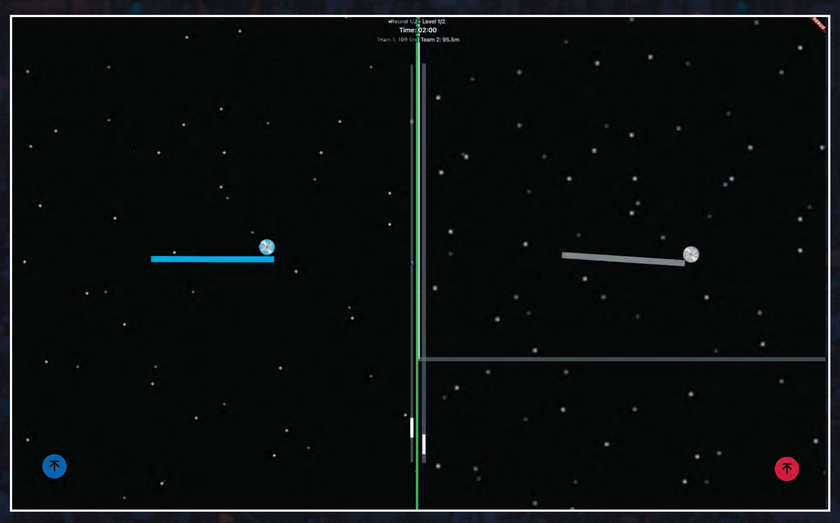
Scaling from single-person or dyadic experiments includes several challenges

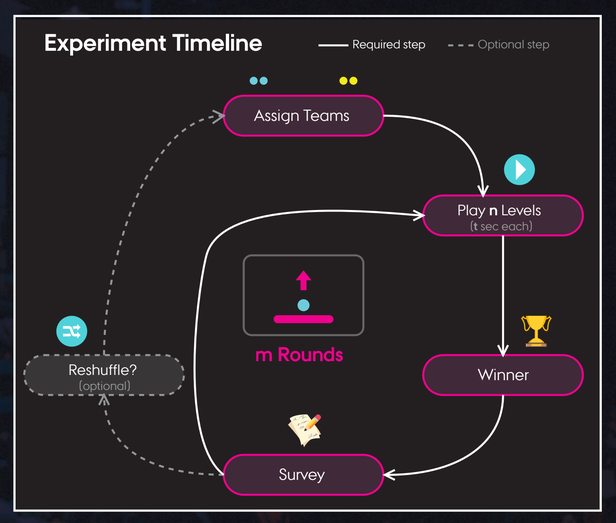
- **Device coordination**: Connecting, configuring and synchronizing multiple participants' inputs across different hardware devices requires a robust communication infrastructure.
- **Latency management**: End-to-end latency (the time between action and visual feedback) is often underreported in group studies, yet it has potential effects on coordination dynamics and can critically impact subsequent analyses.
- **Cross-lab reproducibility**: Different laboratories use varying hardware setups, making it difficult to replicate findings or conduct multi-site studies without consistent timing or without reporting latencies
- **Multimodal integration**: Joint action research increasingly incorporates physiological measures (EEG, EMG, eye tracking), and collected data needs aligning
- **Tools and methods**: PsychoPy and other experiment frameworks are ill-suited to apply in group experiments due to a lack of multi-device support
- **Inter-device synrchony**: Ensuring device clocks and timestamps are synchronized and can be aligned

Here we present and outline a paradigm that provides a novel method of investigating team-based collaboration and competition

We adopt a gaming approach, which affords a high level of experimental control and ecological validity.

Task — a simple video game





Teams collaborate to elevate a virtual ball to maximum height possible before the trial ends. Each team controls one paddle, within each team, participants proportionally control the paddle's propulsion (left/right/neutral). Winning = getting the ball to a higher peak elevation than the other team. Success requires within-team coordination while competing against other teams.

Paradigm Features

Scalable: Task difficulty naturally adapts to group size

Continuous measurement: Moment-to-moment coordination metrics

Flexible team configurations: Study effects of group size, composition, and dynamics

Rich behavioral data: Capture timing, synchrony, leadership emergence, learning, and adaptation

Expandable: Possible to configure physics, experiment parameters, add AI players, etc.

Manipulable Independent Variables

- What is the relationship between group size and coordination efficiency?
- Do new coordination strategies emerge at specific group sizes?
- How do groups adapt to member changes?
- What distinguishes successful from unsuccessful team coordination?

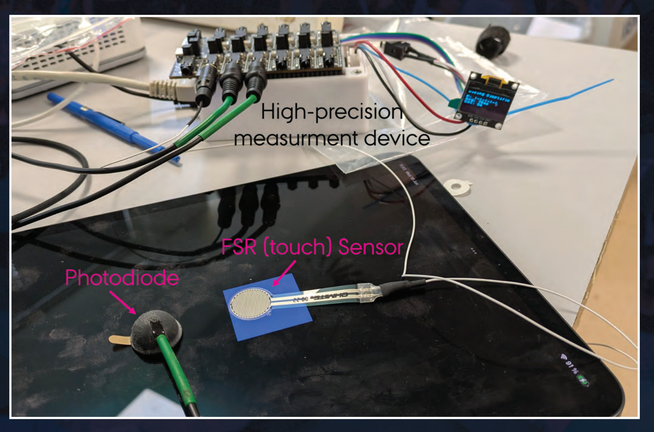
Measurable Dependent Variables

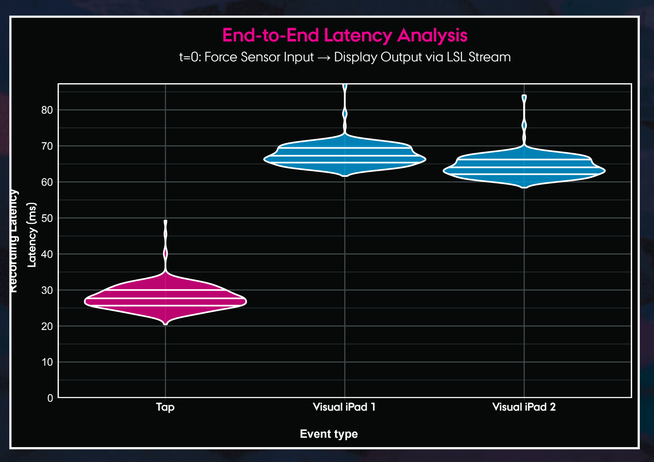
Data collected from the paradigm, includes:

- Continuous reporting of player actions
- Team wins / losses
- Ball coordinates
- Paddle elevation and angle
- Team membership / changes
- Post-round survey data

Validation of experimental platform

- It is critical that any novel platform for measuring group interaction be validated for measurement accuracy and precision.
- Why? (see: **Measuring Multimodal Group Synchrony: Key Challenges**)
- To address some of the challenges we have developed an open-source library for aiding the synchronization of multimodal group experiments.
- The library can be deployed on many devices and operating systems. Built around the established Lab Streaming Layer (LSL) library, this platform provides:
  - A suite of application for automated latency measurement, compensation and reporting
  - Hardware agnostic deployment
  - Easy multimodal integration via LSL
  - Scalable architecture for 2 or more devices
- We extensively tested the timing of the experimental platform
- Established ground truth end-to-end latency (see: **Measuring multimodal group synchrony: key challenges**)





Conclusion

Joint action research stands at an exciting inflection point. By providing tools to study coordination beyond dyads in a controlled manor, we open new avenues for understanding how humans participate in collective behavior and bridge the gap between naturalistic and observational studies in large groups and dyadic lab studies. This framework represents not only a technical solution, but an invitation to collaborate and expand the theoretical and empirical horizons in joint action research.

Future directions

- Initial behavioural study upcoming.
- How can we measure inter-brain synchrony during multiplayer gaming using hyperscanning?[10][11]
- Investigation of within- and across- team differences in synchrony.

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Background photo by Joseph Chan on Unsplash, Videogame photo by JESHOOTS.COM on Unsplash

References

[1] N. Sebanz and G. Knoblich, "Progress in Joint-Action Research," *Curr Dir Psychol Sci*, vol. 30, no. 2, pp. 138–143, Apr. 2021, doi: 10.1177/0963721420984425.
[2] A. Karlinsky, K. R. Lohse, and M. Y. Lam, "A Meta-Analysis of the Joint Simon Effect," *Proceedings of the Annual Meeting of the Cognitive Science Society*, vol. 39, no. 0, 2017, Accessed: Jul. 02, 2025. [Online]. Available: https://escholarship.org/uc/item/9bf4n967.
[3] S. Atmaca, N. Sebanz, W. Prinz, and G. Knoblich, "Action co-representation: The joint SNARC effect," *Social Neuroscience*, vol. 3, no. 3–4, pp. 410–420, Sep. 2008, doi: 10.1080/17470910801900908.
[4] C. Sakata, Y. Ueda, and Y. Moriguchi, "Visual memory of a co-actor's target during joint search," *Psychological Research*, vol. 87, no. 7, pp. 2068–2085, Oct. 2023, doi: 10.1007/s00426-023-01819-7.
[5] F. Elekes and N. Sebanz, "Effects of a partner's task on memory for content and source," *Cognition*, vol. 198, p. 104221, May 2020, doi: 10.1016/j.cognition.2020.104221.
[6] K. L. Marsh, M. J. Richardson, and R. C. Schmidt, "Social Connection Through Joint Action and Interpersonal Coordination," *Topics in Cognitive Science*, vol. 1, no. 2, pp. 320–339, 2009, doi: 10.1111/j.1756-8765.2009.01022.x.
[7] C. Vesper, R. P. R. D. van der Wel, G. Knoblich, and N. Sebanz, "Are you ready to jump? Predictive mechanisms in interpersonal coordination," *Journal of Experimental Psychology: Human Perception and Performance*, vol. 39, no. 1, pp. 48–61, 2013, doi: 10.1037/a0028066.
[8] M. Balconi and M. E. Vanutelli, "Cooperation and Competition with Hyperscanning Methods: Review and Future Application to Emotion Domain," *Front. Comput. Neurosci.*, vol. 11, Sep. 2017, doi: 10.3389/fncom.2017.00086.
[9] F. Cui, X. Zhu, F. Duan, and Y. Luo, "Instructions of cooperation and competition influence the neural responses to others' pain: An ERP study," *Social Neuroscience*, vol. 11, no. 3, pp. 289–296, May 2016, doi: 10.1080/17470919.2015.1078258.
[10] A. Zamm _et al._, "A practical guide to EEG hyperscanning in joint action research: from motivation to implementation," *Social Cognitive and Affective Neuroscience*, vol. 19, no. 1, p. nsae026, Jul. 2024, doi: 10.1093/scan/nsae026.
[11] Aarhus University, "Large-scale Hyperscanning - Center for Ear-EEG, Aarhus University," Aarhus University. Accessed: Jul. 03, 2025. [Online]. Available: https://ece.au.dk/en/research/research-centres/center-for-ear-eeg/projects/large-scale-ear-eeg-hyperscanning