Do we make good partners? Modeling auditory-motor synchronization in a social turn-taking context

Bégel, V. [1], Demos, A.P. [1,2], & Palmer, C.[1]

[1]Sequence Production Lab, Department of Psychology, McGill University, Canada

[2]University of Illinois at Chicago, US

Sequence Production Lab

Introduction

1. Auditory-motor synchronization changes in a social context:

- Synchronization can be improved in a social (group) context (Kirschner & Tomasello, 2009)

2. Spontaneous Production Rate (SPR):

- Natural uncued rate at which individuals produce regular musical sequences (Zamm et al., 2016; Scheurich et al., 2018)
- Larger differences between individuals' SPRs reduce synchronization accuracy in group coordination (Palmer et al, 2019; Zamm et al., 2016)

3. Delay-coupling models:

- Coupled nonlinear dynamical systems can capture anticipatory synchronization (Voss, 2000; Stepp & Turvey, 2010)
- Coupling strength & time delay can capture properties of solo and group synchronization (Demos et al., 2019)

$\dot{\theta}_1 = \omega_1$ Driver oscillator (metronome)

$\dot{\theta}_2 = \omega_2 + k_2(\theta_1 - \theta_{2\tau_2})$ Driven oscillator (tapper)

Intrinsic frequency $\omega_{diff} = \omega_2 - \omega_1$

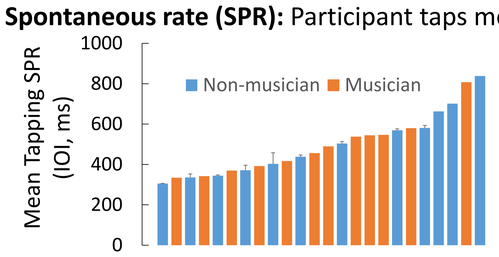
Participant's Coupling strength

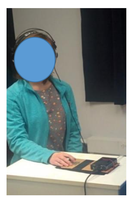
Participant's Time delay

Methods

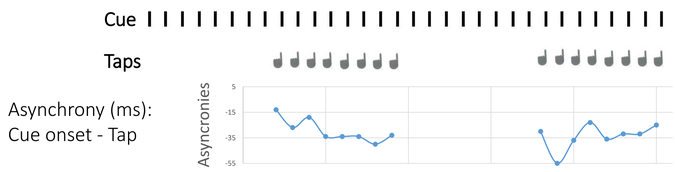
Participants: 24 adults, normal hearing
Musically untrained (n = 12) and trained (n = 12)

1) Spontaneous rate (SPR): Participant taps melody at steady (uncued) rate

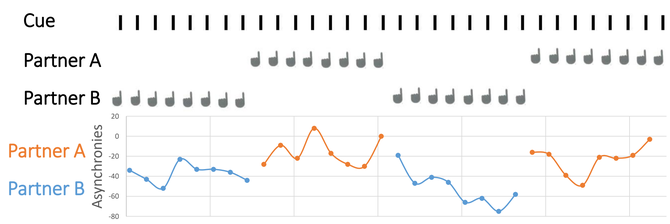


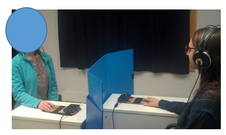


2) Solo Synchronization: Participant taps melody with auditory cue set to their own SPR, and then to their partner's SPR (tap 8 beats, wait 8 beats)



3) Joint Turn-taking: Participants take turns synchronizing with auditory cue set to SPR of PartnerA, then PartnerB





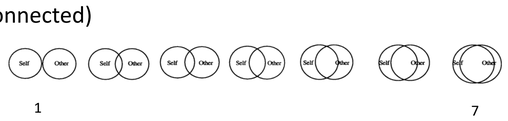
4) Social questionnaire

Synchronization: How successful do you think your synchronization was with your partner? (1=not synchronized, 7=totally synchronized)

Pleasantness: How unpleasant or pleasant did you find the experience of playing with the other participant? (1=unpleasant, 7=pleasant)

Connectedness: Overall, I feel connected to the person in the experiment with me. (1=not connected, 7=totally connected)

Relationship With Partner:



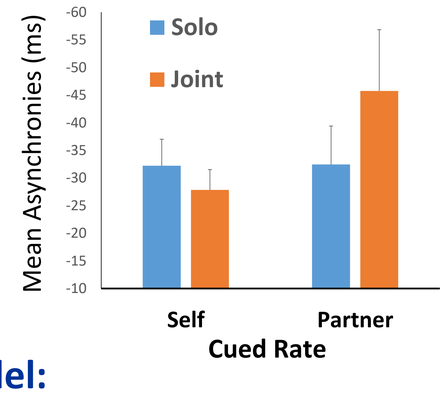
Results

1. Cued rate effect:

Joint Condition: Greater synchrony when partners tap at their own Spontaneous Rates

Cued Rate X Solo/Joint ($p < .05$)

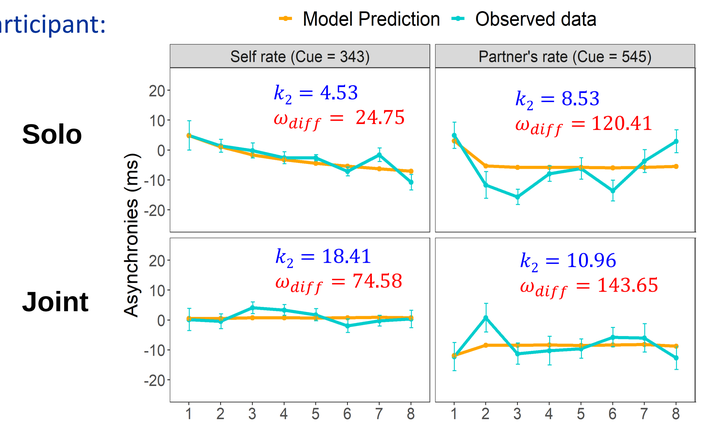
No effect of musicianship



2. Delay-Coupling Model:

Coupling strength, k_2: Musicians > Nonmusicians *(t-test, $p < .05$)*

Sample participant:



Time delay (τ =10.15) fixed across participants
RMSE used to select best model fits

Coupling strength (k_2) increases as SPR Difference |PartnerA-PartnerB| increases (Ancova, $p < .05$)

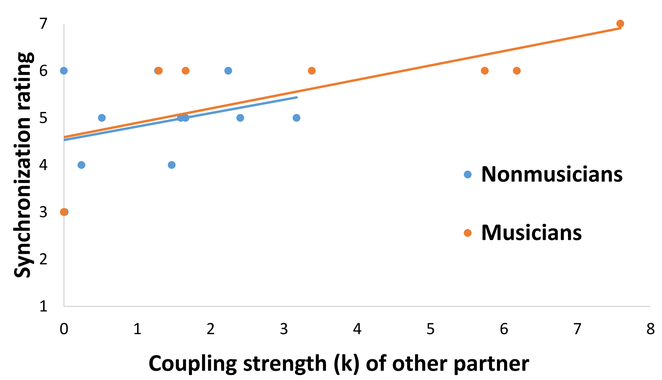
3. Social Interaction ratings

Synchronization Ratings: Musicians (5.87) > Nonmusicians (4.58) *(Wilcoxon test, $p < .05$)*

High correlations between questions

	Pleasantness	Connectedness	Relationship	Synchronization
Pleasantness				
Connectedness	.59**			
Relationship	.65**	.77**		
Synchronization	.75***	.47*	.37	

Synchronization ratings increase as other partner's coupling strength (k_2) increases in the joint condition at the partner's rate (r = .62, $p < .05$)



Discussion

- Spontaneous Rates affect Synchronization
  - SPRs provide evidence for different intrinsic frequencies
  - Larger asynchronies when cued rate is farther from tapper's spontaneous rate in Joint synchronization
- Delay-coupling model
  - Model captures synchronization with and without social context (Solo, Joint) at both Self and Partner's rates
  - Synchrony ratings correlate with Partner's coupling strength (model fit) only in Joint synchronization at partners' rate
- Social Interaction ratings
  - High correlations between Partners: Pleasantness, Connectedness, Relationship and Synchronization
  - Musicians rated Synchrony higher, even when Musicians were not more synchronous than Nonmusicians
- Future directions
  - Develop validation principles for nonlinear models, based on surrogate pairings (non-Partner dyads)
  - Cross-validation of the delay coupling model
  - Further explore the role of spontaneous rates on social interactions

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Acknowledgments

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