Modelling learning to synchronize in a social turn-taking context

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Introduction

How do people learn to synchronize?

- Does synchronizing with a partner improve one's ability to synchronize with an auditory cue?
- Can a delay-coupling model capture learning to synchronize?

Turn-Taking & Synchronization

- Turn-taking is required in many activities, such as conversation or group music-making (Zamm et al., 2021)
- Musical turn-taking often requires keeping synchronization between partners
- Synchronization with a steady cue can be influenced by the presence of a partner (Bégel et al., 2022; Zamm et al., 2016)
- Musically trained individuals can synchronize flexibly across rates (Scheurich et al., 2018)
- Untrained individuals are more constrained by their spontaneous (uncued) production rate (Tranchant et al., 2022)

Modelling Synchronization

- Learning to synchronize can be modelled using a delay-coupled model (Demos et al., 2019; Stepp & Turvey, 2010; Voss, 2000), unidirectional influence

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

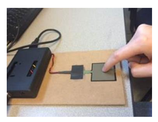
$\dot{\theta}_2 = \omega_2 + k_2(\theta_1 - \theta_{2\tau_2})$ Driven oscillator (tapper)

Intrinsic frequency $\omega_{diff} = \omega_2 - \omega_1$ — Participant's Coupling strength — Participant's Time delay

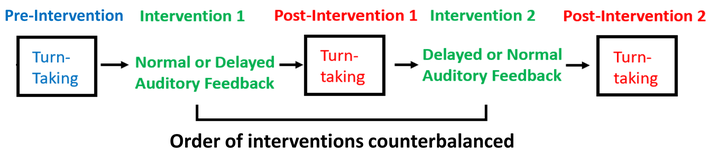
Methods

Participants: N = 48 adults (age range: 18-34 years, M = 23.04)
24 Musically Untrained (training range: 0-1.5 years, M = 0.375)
24 Musically Trained (training range: 6-16 years, M = 10.06)

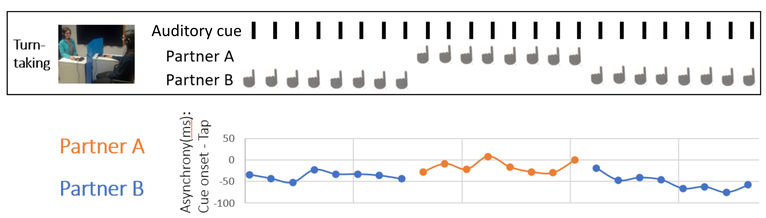
Spontaneous production rate (SPR): Produce a melody at an uncued rate



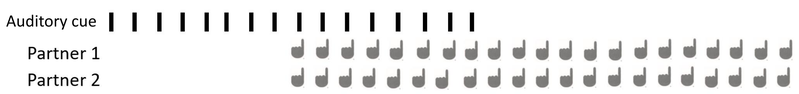
Three Main tasks performed by partners:



1. Turn-Taking (Pre- and Post-Intervention): Partners take turns tapping with auditory cue set to partners' mean spontaneous rate (SPR)



2. Intervention: Participants synchronize together (initial cue = mean SPR) during:
a) Normal auditory feedback and
b) Delayed feedback: 25% of tones randomly delayed by 30-70 ms



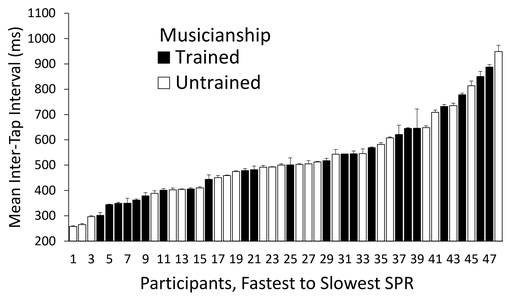
Modelling

- 10 model simulations with optimal time delay fixed: τ = 21.00493
- Best fits = lowest RMSE (root mean squared error)
- SPR difference is modelled with $\omega_2 - \omega_1$ (cued rate – tapper's rate)

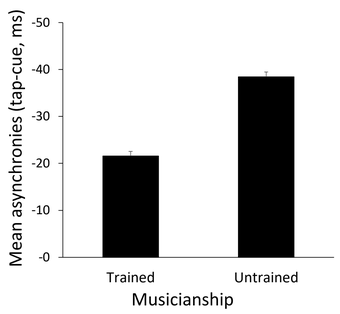
Results

Spontaneous Production Rate

- Rate at which the melody is tapped (without cue)
- Used to fit the model's intrinsic frequency, ω_2, and to set the cued rate, ω_1
- SPRs do not differ for Musically Trained and Untrained participants

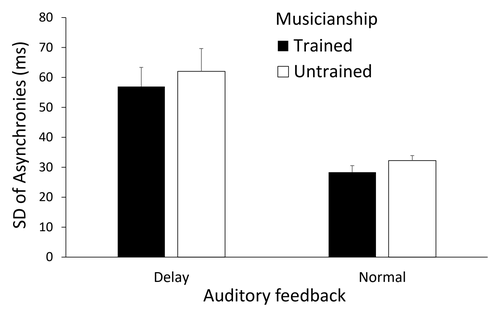


Pre-Intervention Synchrony



Mean asynchrony: Untrained > Trained, $F(1, 46) = 4.19$, $p < .05$, $\eta_G^2 = .084$

Intervention Synchrony

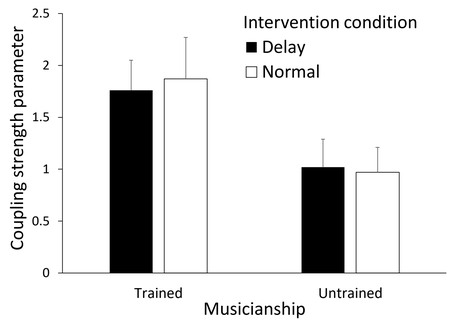


SD of asynchrony: Delay > Normal, $F(1, 22) = 32.69$, $p < .001$, $\eta_G^2 = .419$

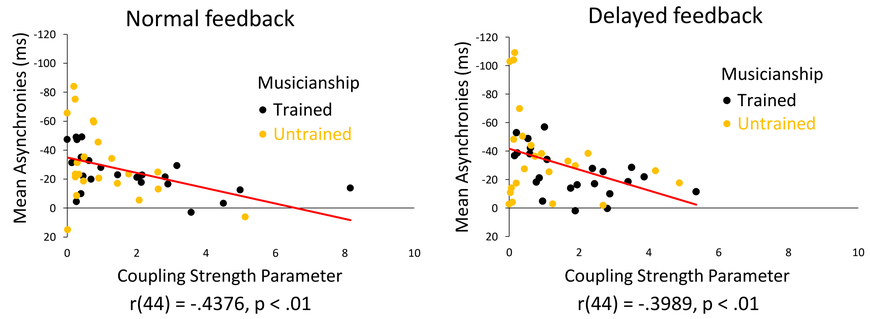
Delay-Coupling Model Applied to Asynchrony (Post-Intervention)

Musicianship affects **coupling strength** (k): Trained > Untrained,
$F(1, 46) = 4.97$, $p < .05$, $\eta_G^2 = .072$

No significant effects on Intrinsic Frequency



As Coupling Strength Increases, Post-Intervention Asynchrony decreases



r(44) = -.4376, p < .01

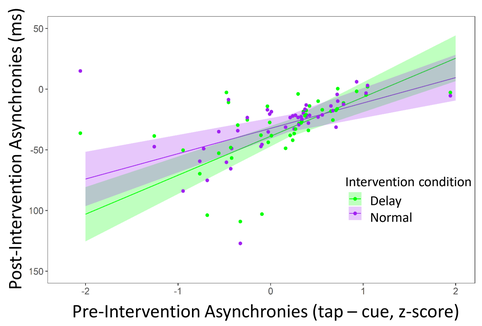
r(44) = -.3989, p < .01

Coupling strength corresponds to mean asynchronies Post-Intervention: Consistent across Intervention conditions

Post-Intervention Synchrony

Delayed feedback at Intervention disrupts Post-Intervention synchrony more in participants with larger Pre-Intervention asynchrony.

Significant interaction:
Intervention Type X Pre-Intervention synchrony,
$F(1, 46) = 6.17$, $p < .05$



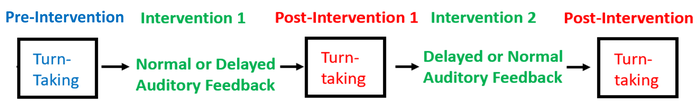
Discussion

How do people learn to synchronize?

- Coupling strength increases with musical training and synchrony accuracy increases with coupling strength
- Findings suggest that years of training improved synchrony accuracy
- Synchrony variability during Interventions increases with altered feedback; does not increase with musical training

Synchronizing with a Partner Affects Post-Intervention Synchronizing with an Auditory Cue

- Delayed feedback disrupted individuals at Post-Intervention who had larger Asynchronies at Pre-Intervention
- Model's coupling strength captured Post-Intervention synchrony differences



Future directions

- Compare delay-coupling with other models
- Examine whether time delay differs across individuals
- Model Pre-Intervention synchrony (individual differences related to musical training)
- Model synchronization during the Interventions

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