Individual Musician's Spontaneous Performance Rates Affect Interpersonal Synchrony in Joint Musical Action: A Dynamical Systems Approach

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Background

Spontaneous Production Rates affect Synchronization

- Interpersonal synchronization occurs when two musicians play together and coordinate their actions.
- Interpersonal synchronization is affected by an individual's spontaneous performance rates (SPRs) [2,3].
- Greater differences between two synchronizing individuals' SPRs result in greater asynchronies between their taps.

Synchronization with Oscillatory Dynamical Systems

- Using a dynamical system of non-linear oscillators, we explain the relationship between SPRs and interpersonal synchrony.
- An oscillator with a fixed spontaneous cycling rate (SCR) simulates an individual's SPR.
- Hebbian learning lets the oscillator adapt its cycling rate to match the frequency of external stimuli.

Hypothesis

Non-linear oscillators with SCR, frequency learning mechanisms, and elasticity, can explain how SPRs affect interpersonal synchronization.

Model

Dynamical System:

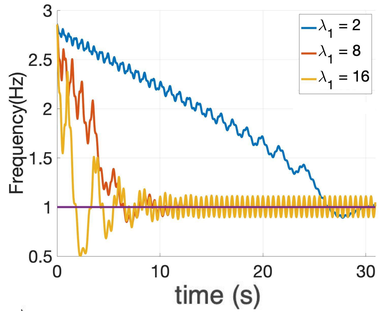
$$\frac{1}{f}\dot{z} = z(\alpha + i2\pi + \beta|z|^2) + F \qquad (1)$$

$$\frac{2\pi}{f}\dot{f} = -\lambda_1 \cos F \sin(\arg z) - \lambda_2 \frac{f_0 - f}{f_0} \qquad (2)$$

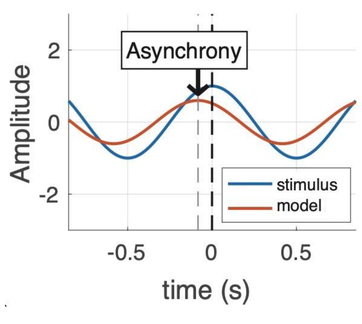
- Equation (1) is a periodic Hopf oscillator described by Large and colleagues [1].
- α and β in (1) are fixed parameters with values 1 and -1, respectively.
- $\dot{z}$ shows limit cycle behavior with unitary magnitude.
- F is the external stimulus $F = exp(i2\pi f_s t)$ where f_s is a fixed frequency.
- Equation (2) is the Hebbian learning rule allowing the oscillator to adapt its cycling rate to match the frequency of the external stimulus [2].
- λ_1 is the learning rate and λ_2 is the elasticity force that pulls the oscillator to its original SCR.

Synchronization Dynamics:

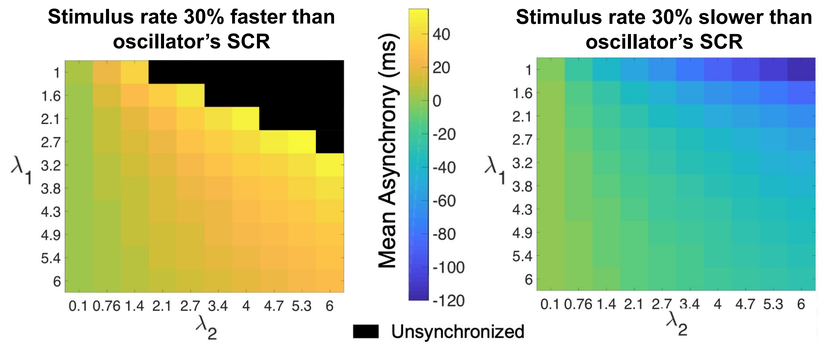
Frequency Learning (1Hz)



Measuring Asynchronies

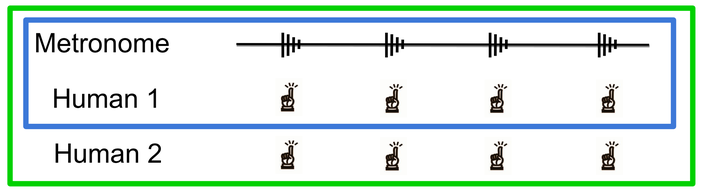


Parameter Analysis

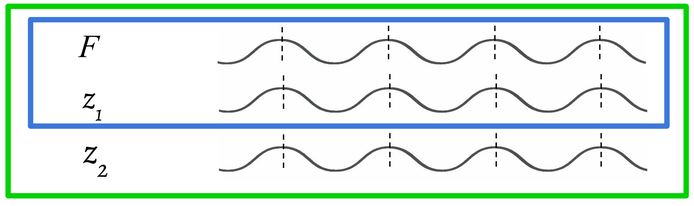


Simulations

Human Tasks



Model Simulations



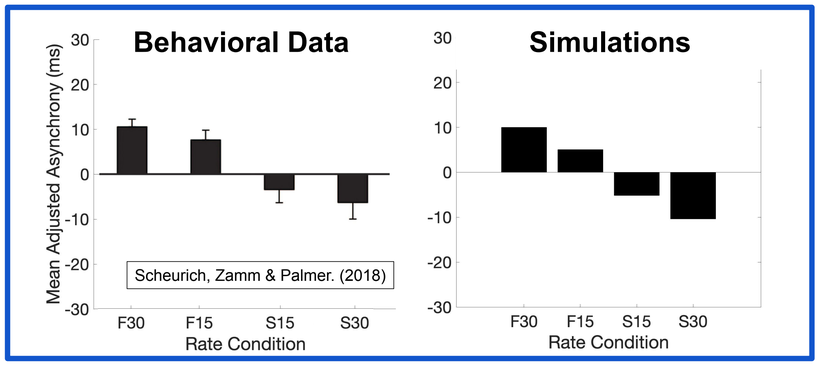
$$\frac{1}{f_1}\dot{z_1} = z_1(\alpha + i2\pi + \beta|z_1|^2) + z_2 + F$$

$$\dot{f_1} = -\lambda_1 \text{real}\{z_2 + F\}\sin(\arg z_1) - \lambda_2 \frac{f_1(0) - f_1}{f_1(0)}$$

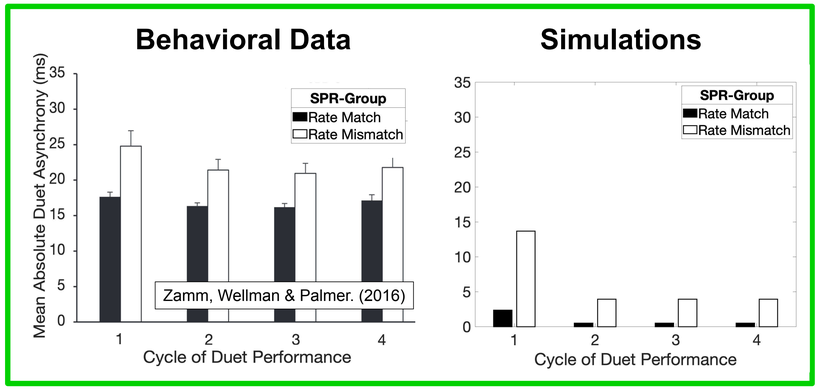
$$\frac{1}{f_2}\dot{z_2} = z_2(\alpha + i2\pi + \beta|z_2|^2) + z_1 + F$$

$$\dot{f_2} = -\lambda_1 \text{real}\{z_1 + F\}\sin(\arg z_2) - \lambda_2 \frac{f_2(0) - f_2}{f_2(0)}$$

Results



Exp 1: Simulation of human asynchronies when tapping with four different metronome rates deviating around an individual's SPR [2]. Due to faster of slower SCR compared to the stimulus frequency, our model shows the anticipating and lagging behavior seen in humans.



Exp 2: Simulation of asynchronies between partners with matching and mismatching SPRs jointly tapping a melody over four consecutive time periods of equal length [3]. Our model replicates the behavioral data, showing greater asynchrony for the "mismatching" condition.

Conclusions

- Our model accounts for a variety of synchronizing behaviors observed in human data.
- The relationship between SPRs and interpersonal synchronization can be simulated using oscillators with different SCRs that synchronize with each other, like humans do.
- This biophysical model homeostatically explains anticipatory action.

References

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Acknowledgements

The authors would like to thank Dr. Edward Tavernetti and Dr. Takako Fujioka for valuable feedback during the preparation of this poster.

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