

Biases in Production and Perception of Auditory-Motor Synchronization



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Introduction

Do individual biases in production of synchrony influence perception of auditory synchrony?

Individuals tend to produce familiar musical sequences at regular spontaneous rates:

- Dynamical systems account of natural frequencies (Zamm et al., 2016, 2018; Palmer et al., 2019)
- Production and perception must align for performers to synchronize in ensembles

Does musical training give performers superior perception of synchrony?

- Beat Alignment Test: Compare synchrony of clicks phase-shifted from musical tones (Iversen & Patel, 2008)
- Musical training associated with greater detection of asynchrony (Harrison & Müllensiefen, 2018)

Perception of synchrony may entail other sensory constraints:

- Two auditory events must be separated by **15-20 ms** for listeners to accurately report temporal order (Hirsh, 1959)
- Temporal order perception also influenced by stimulus duration, intensity, and frequency (Goebel & Parncutt, 2002; Micheyl et al., 2010; Szymaszek et al., 2006)

Method

Participants

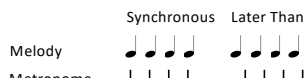
- 18-35 years old, no hearing impairments
- **52 participants with more musical training: "Musicians"** 6-19 years of musical training (mean = 10.6 years)
- 52 participants with less training: "Nonmusicians" 0-2 years of musical training (mean = 0.7 years)

Stimulus Materials

Production task: "Mary Had a Little Lamb" sung on "da"

- Familiar melody sung at a regular rate
- Sung tempo = spontaneous production rate (SPR)

Perception task: Same melody with metronome clicks either Earlier than, On time, or Later than Melody



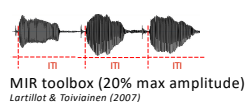
- Melody at **5 Tempi** centred around each SPR: -20% (faster), -10%, SPR, +10%, +20% (slower)
- Metronome at **phase Shifts relative to melody tones**: -40 ms (earlier than melody), -20 ms, 0 ms (synchronous), +20 ms, +40 ms (later than melody)
- Within-subject design: **5 Tempi X 5 Shifts X 2 repetitions**

Procedure

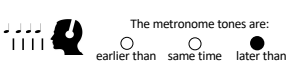
1. Production Task via Vocaroo.com



2. Compute SPR (Mean InterTone Interval) MIR toolbox (20% max amplitude) Lartillot & Toivainen (2007)

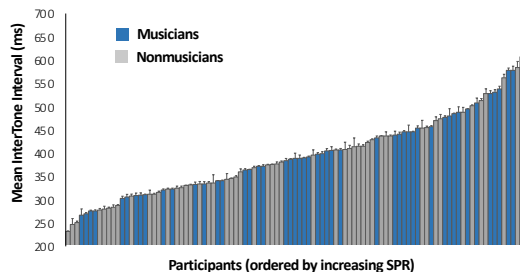


3. Perception Task via Pavlovlab.org (Pierce et al., 2019)



Results

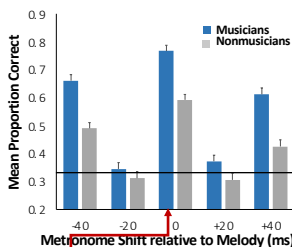
1. Spontaneous Production Rates Differ Between Individuals



2. Musical Training Affects Perception of Synchrony

Participants divided by musical training (0-2 years / 6+ years):

- 3-Way ANOVA:
- Main effect of Shift ($p < .001$)
 - Main effect of Musicianship ($p < .001$)
 - Musicians performed significantly better than Nonmusicians
 - No effect of Tempo



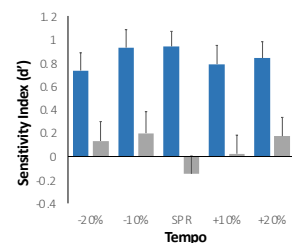
Do participants show a response bias to say "Synchronous"?

Sensitivity independent of response bias:

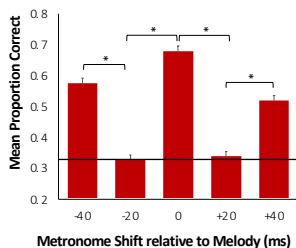
- d-prime (d') = $z(\text{hits}) - z(\text{false alarms})$
- Signal = +40ms Shifts (presence of asynchrony)

ANOVA:

- Main effect of Group ($p < .001$)
- Musicians were more sensitive to asynchronies than Nonmusicians



3. Phase Shifts Affect Perception of Synchrony



ANOVA by Phase Shift and Tempo:

- Significant effect of Metronome Shift ($p < .001$)
- 0ms and +40ms Shifts > +20 ms
- No significant differences by Tempo

+20ms Shifts not significantly different from each other or chance

Discussion

Biases in Production and Perception

- Large range of spontaneous tempi across participants, consistent with individual differences in natural frequencies (Zamm et al., 2016, 2018; Palmer et al., 2019)
 - Not dependent on musical training
- Perception of synchrony not clearly enhanced at performance tempo
 - Do natural frequencies of vocal production differ from perceptual mechanisms?

Musical Training Effects on Perception

- Participants with **greater musical training** showed greater sensitivity to tone asynchronies
- Range of asynchronies was too small for listeners with less training to reliably discriminate temporal order

Phase Shift Effects on Perception

- Listeners less sensitive to asynchronies of **20 ms**
 - Minimum phase shift for perception of temporal order with simple tones and clicks (Hirsh, 1959)

Limitations & Future Directions

- Effect of tempo across 20% range not significant (Scheurich et al., 2016)
- Online: Limited control over listening environment
- No audiometric screening → include online hearing test

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Acknowledgments

We thank Lucas Carneiro and Jocelyne Chan for their assistance



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