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# Modeling the subjective beat in period, phase and uncertainty

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A methodology to capture ambiguity in the beat in both period and phase by obtaining a 2d distribution from free tapping data from multiple listeners.



## Previously...

• The beat is not perceived equally by all listeners, whom may express it using different tapping periods or phases.

• The ambiguity of the beat has been looked into, mostly inspecting differences in selected tapping rate [Moelants, 2002, Moelants and McKinney, 2004, McKinney and Moelants, 2004].

Pulse clarity has been captured computationally [Lartillot et al., 2008,

# What's New

• We propose modelling the **subjective experience** of the beat as a 2d distribution of period and phase.

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- We provide a methodology to gather this distribution from free tapping data (including mid-stimulus beat changes) from several annotators [Miguel and Slezak, 2021].
- We evalated whether **multiple beats being possible** is related with **pulse** clarity.

## Did it work?

- The methodology was evaluated on simulated taps. It recovered the correct period and phase with high probability and captured the probability of a beat as the proportion of time or number of tappers that expressed it.
- We present the methodology applied to three distinct free-tapping datasets including rhythms and music.

Pironio et al., 2021]. We wonder whether multiple tacti being possible affects this feature.

• We found significant correlations between entropy of the distributions and objective and subjective measures of pulse clarity.

## The Distribution

- We consider isochronous tacti, described by a period and a phase.
- To capture ambiguity, we evaluate the probability that different tacti are selected by listeners.
- We propose describing the distribution as a discrete 2d grid:
- period: inter-beat interval time
- phase: relative location in the range [0, 1] within the period



## The Methodology





**2:** A period and phase is fit to each segment using a linear regression (period = slope, phase = (intercept mod slope)/slope).

**3:** Each segment contributes to its beat bin the number of time frames it overlaps with. A final distribution is calculated by normalizing each bin's frame count.

#### Do multiple possible tacti affect pulse clarity?

- Pulse clarity is a feature commonly used in music psychology.
- It is often calculated computationally, with no detail on what musical features affect this magnitude.
- We evaluated whether pulse clarity obtained as tapping variability and difficulty reports was affected by beat ambiguity:
- **Tapping variability:** coefficient of variation of the inter-tap interval distribution for each tapping segment, z-scored by participant.
- **Tapping difficulty:** reported difficulty for indicating the beat, z-scored by participant.
- **Beat ambiguity:** entropy of the 2d distribution estimated from population tapping data.
- Beat strength: proportion of time where a beat was produced by the listeners.



#### Application to datasets

습 0.4 -

0.2 -

Period (IBI)





 Tapping recordings paired with EEG [Losorelli et al., 2017]. 20 participants 10 song excerpts (35" each) Unfamiliar songs with stable beat





Wide range of tempi (55-150 bpm)



r value is for partial Spearman correlation between the variables (controlled for tapping variability)



Period (IBI)

250

#### Rhythms

- Free tapping data [Miguel and Slezak, 2021] (mid-stimulus changes and pauses of beat tapping were allowed)
- 30 participants

• 28 rhythms of varying complexity (24-31" each) Beat tapping difficulty was provided for each trial