Martin A. Miguel
mmiguel@dc.uba.ar

# A continuous model of pulse clarity

## Towards inspecting affect through expectations in time

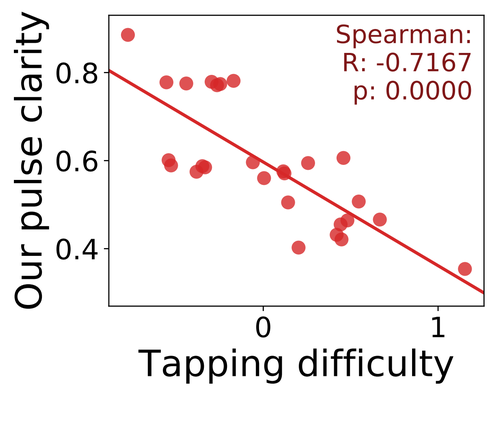
cor.to/
m2_smpc2019_2

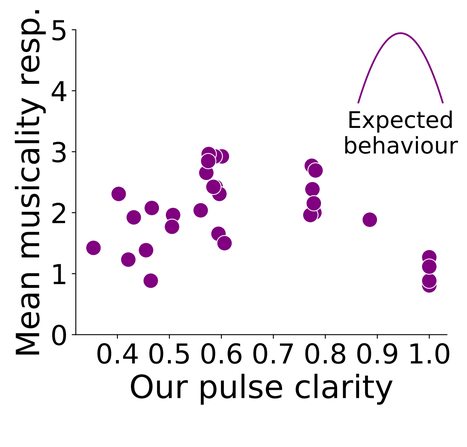
Martin A. Miguel [1,2] Mariano Sigman [3] Diego Fernandez Slezak[1,2]

[1]Universidad de Buenos Aires. Facultad de Ciencias Exactas y Naturales. Departamento de Computación. Buenos Aires, Argentina [2]CONICET-Universidad de Buenos Aires. Instituto de Investigación en Ciencias de la Computación (ICC). Buenos Aires, Argentina [3]Laboratorio de Neurociencia Integrativa. Universidad Torcuato Di Tella. Buenos Aires, Argentina.

TL; DR

A model of **pulse clarity** that develops **in time** globally correlates with **tapping difficulty** and presents an **inverted U-shaped** relationship with **musicality**




3' Speech

Grand goal: reach a computational model to analyze affect in music.

### Previously...

- Theories on how music generates **affect** propose they emerge from **unrealized expectations** [Meyer, 1956, Huron, 2006, Vuust and Witek, 2014].
- In rhythms, the beat (or tactus) is the first expectation [Povel and Essens, 1985].
- **Pulse clarity** and **rhythmic complexity** are measures previously related to musical affect [Witek et al., 2014, Trost et al., 2015].
- Musical expectations develop in time. Most rhythmic complexity models provide only an overall metric.

### What's New

**Current goal:**
Develop a model of **pulse clarity** that evolves in time.

- We introduce an agent-based **beat tracking** model for rhythms named **THT**.
- THT works **casually** and provides a continuous metric of **certainty** of the inferred beat.
- The metric should be a proxy for **pulse clarity**.

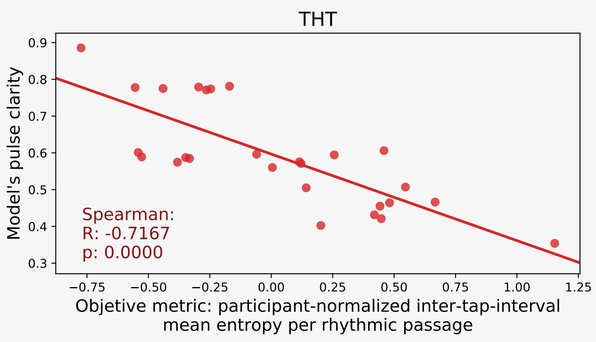
### Did it work?

- We tested overall **beat clarity** to compare with previous work.
- We performed an **experiment** where participants tapped to their subjective beat while listening to rhythmic passages.
- We measured **tapping difficulty** with a question (**subjective** metric) and by analyzing tapping synchrony (**objective** metric).
- Our **pulse clarity** metric correlated significantly with experimental results. It also presented an **inverted U-shaped** relationship with **musicality** and **need-to-move** questions asked to participants.

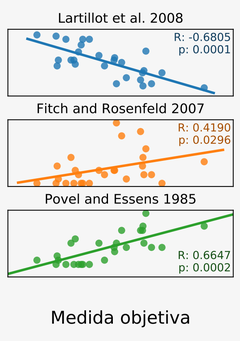
Results

THT's pulse clarity correlates significantly with subjective tapping difficulty.

*Us*

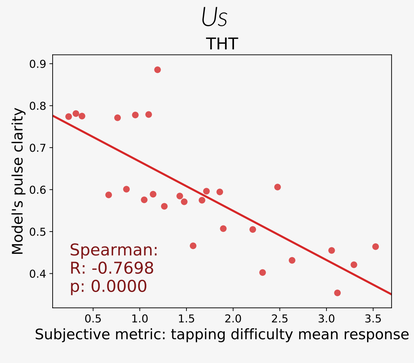



*Other models*




THT's pulse clarity correlates significantly with objective tapping difficulty.

*Us*



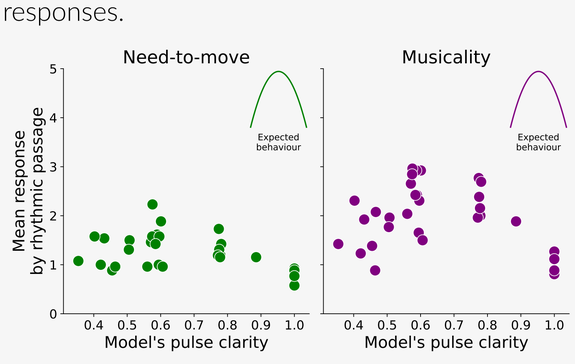

*Other models*

Fitch and Rosenfeld 2007
- R: 0.7380 (p: 0.0000)

Lartillot et al. 2008
- R: -0.6625 (p: 0.0002)

Povel and Essens 1985
- R: 0.9198 (p: 0.0000)

THT's pulse clarity presents an inverted U-shaped relationship with musicality and need-to-move responses.




The Details

## The Model

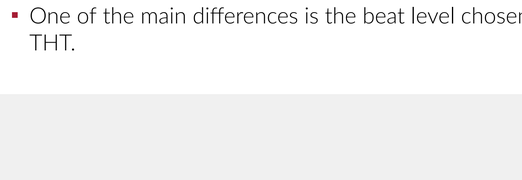
THT is an agent-based model. Each agent keeps tabs on a tactus hypothesis and hence are named **hypothesis trackers**. A possible tactus is represented by a phase ($\rho$) and a period ($\delta$). Trackers are created and updated while listening to the rhythm. Hypothesis have a **certainty score** in [0, 1]. Hypothesis parameters and score evolve overtime.

Input: $(r_{1..N})$ a sequence of onset times in $ms$


Output: a set of **hypothesis trackers** with their history




Hypotheses:




Certainty score:

$$\frac{\text{hits by hypothesis}}{\text{hypothesis events}} \times \frac{\text{hits by hypothesis}}{\text{rhythm events}}$$

Hits between a hypothesis proyection and a rhythmic event score 1 and decay exponentially with the distance.

### Model's behaviour

Main hypothesis score decays when the rhythmic scene changes and main hypothesis changes to adapt.




(a) period change (b) phase change (c) rallentando (d) mixed patterns

Global **pulse clarity** was calculated as the mean score of the main hypothesis over time.

THT beat tracking capabilities were compared with another recognized model on MIREX training dataset.

| Metrics/Models | THT | Dixon 2007 |
|---|---|---|
| Cemgil | 0.3231 | 0.3910 |
| Cemgil Best Metric Level | 0.4500 | 0.4695 |
| P-score | 0.4661 | 0.5725 |

- Scores are close by behind.
- The compared model is not causal (looks into the future).
- One of the main differences is the beat level chosen by THT.

## The Experiment

Task: tap the beat freely while listening to rhythmic examples of varied difficulty.

- 28 participants (8 women)
- Mean age: 28.5 (8.15 sd)
- Mean years of musical training: 4.43 (3.81 sd)
- 33 rhythmic passages




## References

S. Dixon. Evaluation of the audio beat tracking system beatroot. Journal of New Music Research, 36(1):39–50, 2007.

W. T. Fitch and A. J. Rosenfeld. Perception and production of syncopated rhythms. Music Perception: An Interdisciplinary Journal, 25(1):43–58, 2007.

D. B. Huron. Sweet anticipation: Music and the psychology of expectation. MIT press, 2006.

O. Lartillot, T. Eerola, P. Toiviainen, and J. Fornari. Multi-feature modeling of pulse clarity: Design, validation and optimization. In ISMIR, pages 521–526. Citeseer, 2008.

L. B. Meyer. Emotion and meaning in music. 1956. for an important attempt to distinguish image processes, connotations, moods, and affective experience in the apprehension of musical phenomena, pages 256–272, 1956.

D.-J. Povel and P. Essens. Perception of temporal patterns. Music Perception: An Interdisciplinary Journal, 2(4):411–440, 1985.

W. Trost, S. Frühholz, T. Cochrane, Y. Cojan, and P. Vuilleumier. Temporal dynamics of musical emotions examined through intersubject synchrony of brain activity. Social cognitive and affective neuroscience, 10(12):1705–1721, 2015.

P. Vuust and M. A. Witek. Rhythmic complexity and predictive coding: a novel approach to modeling rhythm and meter perception in music. Frontiers in psychology, 5, 2014.

M. A. Witek, E. F. Clarke, M. Wallentin, M. L. Kringelbach, and P. Vuust. Syncopation, body-movement and pleasure in groove music. PloS one, 9(4):e94446, 2014.

ICC

LIAA
Laboratorio de Inteligencia Artificial Aplicada