

TIPPING POINTS, PULSE ELASTICITY AND TONAL TENSION: AN EMPIRICAL STUDY ON WHAT GENERATES TIPPING POINTS

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Summary

Tipping points are moments of change that characterise crucial turning points in a piece of music. This study presents a first step towards quantitatively and systematically describing the musical properties of tipping points. Timing information and computationally-derived tonal tension values that correspond to dissonance, distance from key, and harmonic motion are compared to tipping points in Ashkenazy's recordings of six Chopin Mazurkas as identified by 35 listeners. The analysis shows that all popular tipping points but one could be explained by statistically significant timing deviations or changepoints in at least one of the three tension parameters.

Background

- Tipping points first introduced in [1] referring to temporal deviations that simulate the physical sensation of a tipping point. Implemented in performance through slowing of tempo.
- Temporal tipping points associated with apices of musical tension. This interplay discussed in both [1] & [2].
- However, difficult to rigorously define a tipping point.

Conclusions

- As we expected, listeners often reported perceived tipping points at critical turning points in the music. These commonly fell at high-tension structural boundaries in the pieces, for example at 75-83s in Op 17 Nr 2.
- However, participants may have struggled to wholly grasp the concept. Sometimes, listeners perceived tipping points at structural boundaries which marked the ends of sections in a final and stable way. For example, between 56-60s in Op 33 Nr 1, 57% of participants perceived a tipping point and this was verified by Model 1. 41-45s in Op 33 Nr 1 was also an example and here, neither model verified the response. We do not consider these as tipping points since there is insufficient tension.

Future Directions

- Incorporate information theoretic techniques to measure expectation as a predictor of perceived tension.
- Analyse computationally which musical features elicit strong emotions during a tipping point.

References

- [1] E. Chew: "Playing with the Edge, Tipping Points and the Role of Tonality", *Music Perception: An Interdisciplinary Journal*, 2016 Feb; 33(3): 344-366.
- [2] B. Gingras et al: "Linking melodic expectation to expressive performance timing and perceived musical tension", *J Exp Psychol Hum Percept Perform*, 2016 Apr; 42(4): 594-609.
- [3] D. Herremans, E. Chew: "Tension ribbons: quantifying and visualizing tonal tension", *Proc of the Second Intl Conf on Technologies for Music Notation and Representation (TENOR)*. Cambridge, UK. 8-18.
- [4] R. Killick, I. Eckley: "changepoint: An R Package for Changepoint Analysis". *J of Statistical Software*, 2014; 58(3): 1-19.

1. Data process

- Excerpts of 6 of Chopin's Mazurkas performed by Vladimir Ashkenazy, with data of time of beat instances^a.
- Scores of these Mazurkas, in humdrum file format^b.
- Data from 35 participants of one point in the excerpt which *best* constituted a tipping point. This data was recorded by means of a Google Forms questionnaire^c.

^a<https://github.com/katkost/MazurkaBL>

^b<https://github.com/craigsapp/chopin-mazurkas>

^c<https://goo.gl/forms/wqOSBMTwqwzaD6Hm1>

2. Computational Modelling of Tipping Points

In general, view participants' perception of tipping points as **ground-truth** and design computational models to predict these perceptions.

Model 1

- **Time - based model** which predicts tipping points when the beat duration is larger than specified **threshold**.
- Defining d_i as the duration of beat i in performance time, there is a time-based tipping point at the time where the i^{th} beat starts if:

$$d_i > \bar{d} + 2.5 \times \sigma, \quad (1)$$

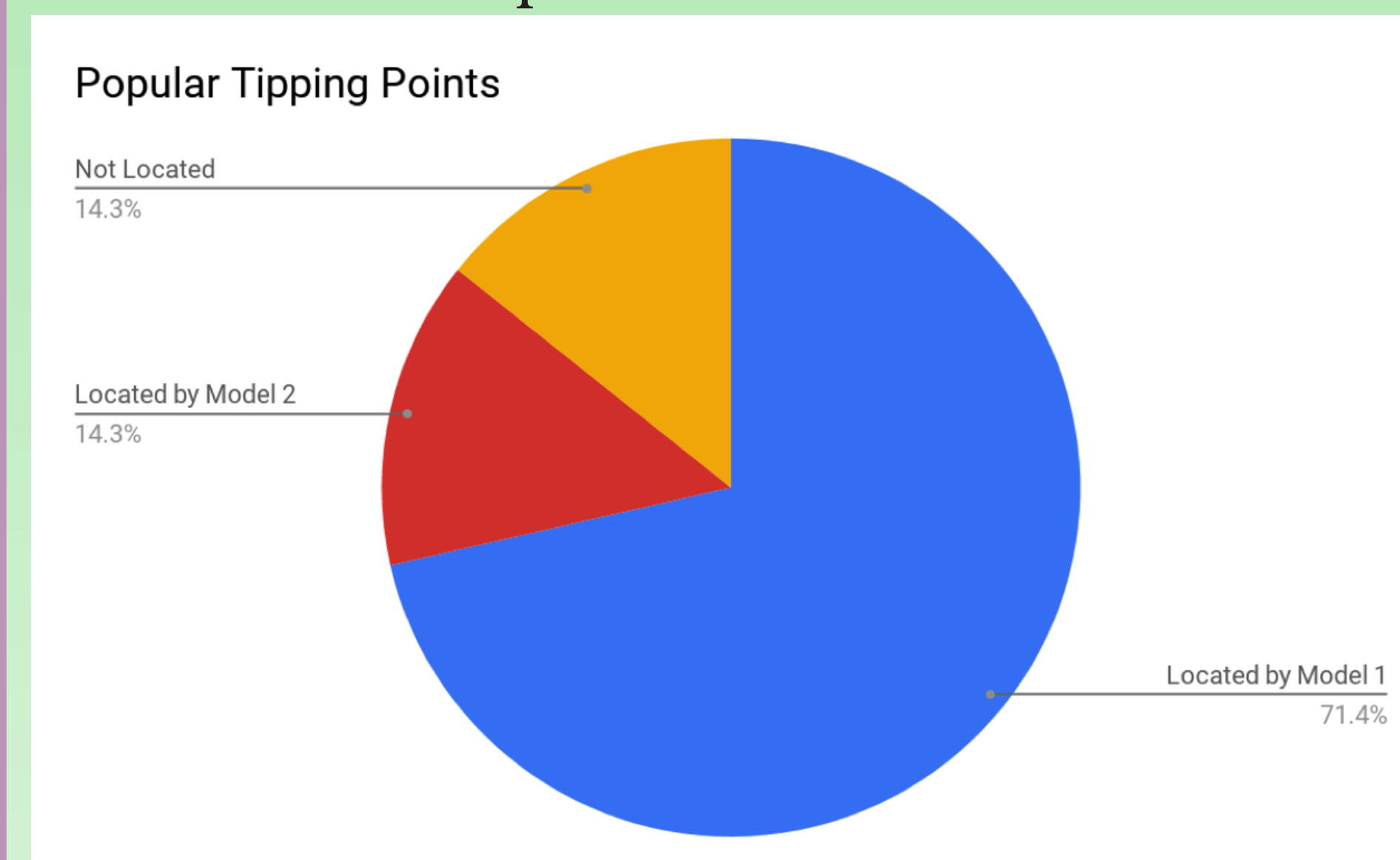
where \bar{d} is the sample mean of the $\{d_i\}$ and σ is the sample standard deviation. The program rejects any tipping points which are found in the first and last three bars of a piece since performers often play at a slower pace in the introductory and concluding passages.

Model 2

- **Tonal tension-based model** which predicts tipping points as statistically significant changes in the mean or variance of the tonal tension data.
- Tonal tension is estimated through the spiral array-based computational model described in [3], which captures aspects of dissonance (cloud diameter), harmonic change (cloud momentum), and distance from key (tensile strain).
- Identify statistically significant change using the 'changepoint' package [4] in R. Especially interested in points where changes represent shifts from **high to low tension**.

3. Results

Proportion of popular tipping points located by computational models:

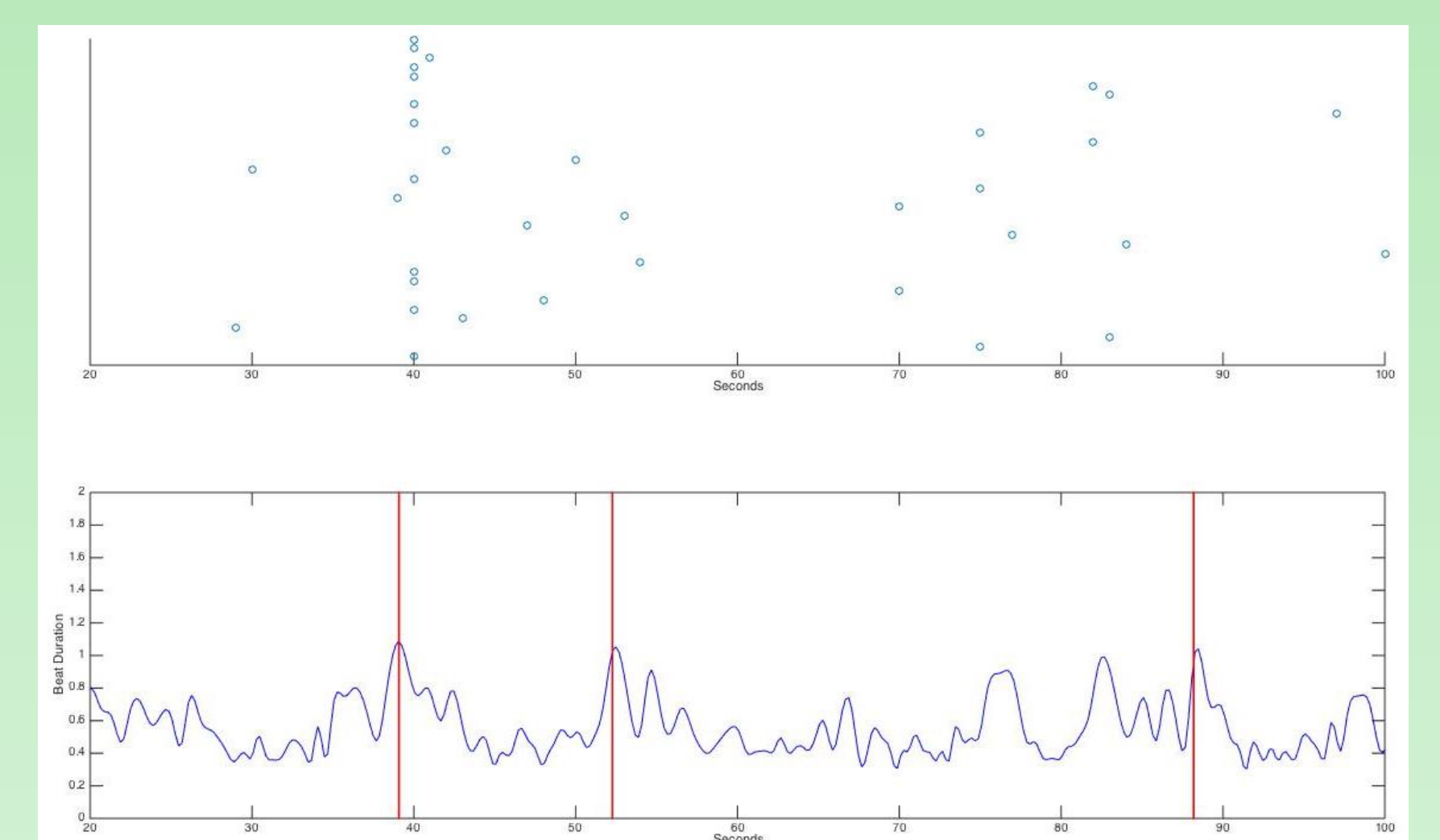


Comments:

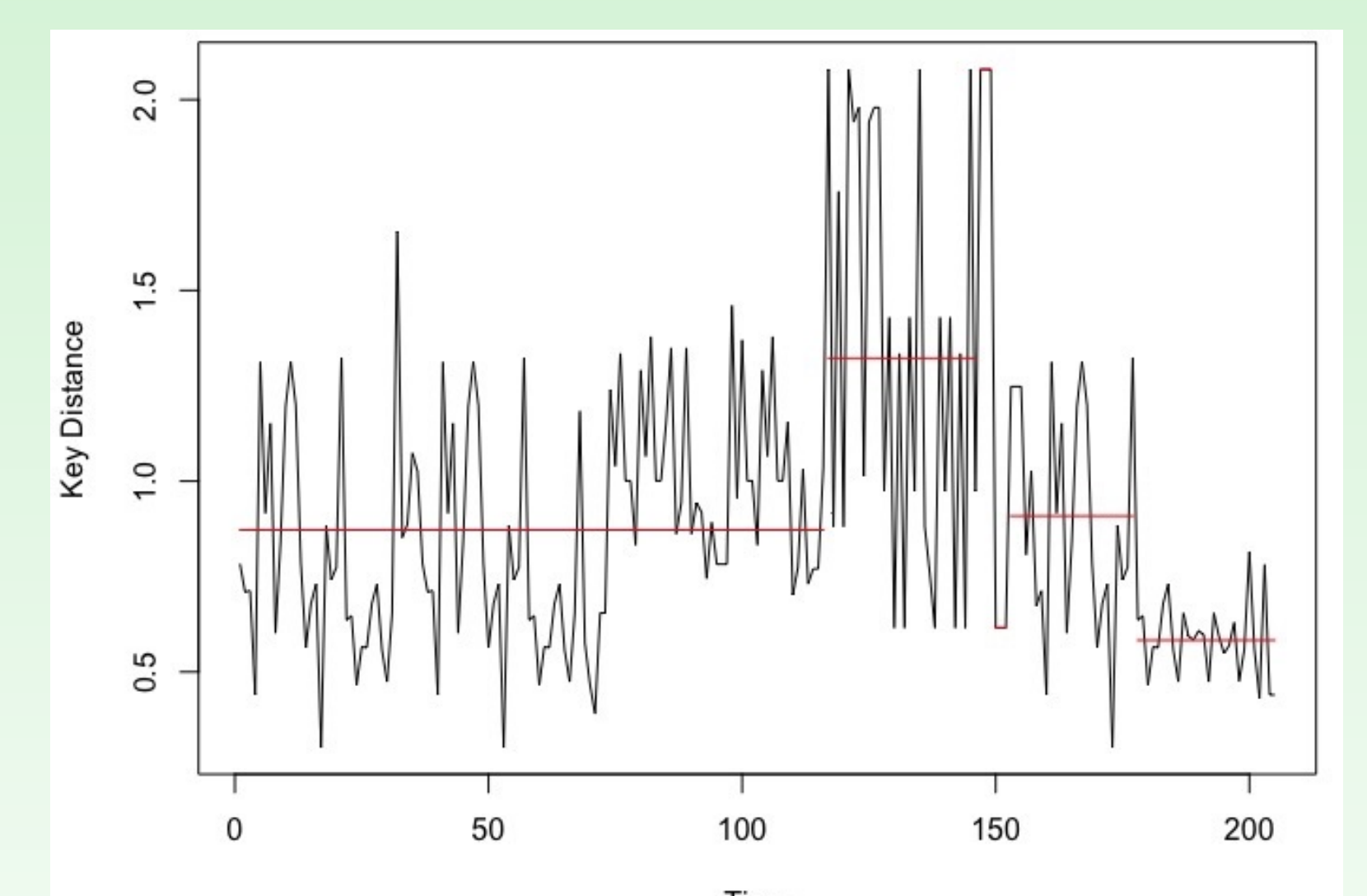
- Defined as popular tipping point if perceived by $\approx 25\%$ or more of participants.
- Across-Mazurka average standard deviation of 15.9 seconds for listener-identified tipping points. Listeners' perceptions were therefore **varied**.
- All but one popular tipping point was located by one of the two computational models.
- The one tipping point not located was an example where listeners perceived a tipping point at the end of a section ending in a stable way. Therefore, agree with the computational model that this is **not** a tipping point.

4. Case Example: Op 17 Nr 2

Scatter plot of perceived tipping points (top); tipping points predicted by Model 1 (bottom):



Changepoints in the key distance parameter:



- 40% of participants perceived a tipping point between 38-42s. Model 1 located this.
- 23% perceived a tipping point between 75-83s. Not located by Model 1, but high-to-low changepoint in key distance located by Model 2.