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A new method for estimating Internal Drift and Just Noticeable Difference in perception of continuous tempo drift

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Abstract

Is there such a thing as an internal representation of a “steady tempo” - and is this representation itself free from tempo drift? To investigate this we propose a new method for studying detection of continuous tempo drift.

Keywords: tempo drift, tempo perception, JND, internal drift

Introduction

The aim for this exploratory study has been to investigate to what extent a continuous tempo drift is perceivable. Whether there is an internal representation of a steady tempo or not is still an open question, however, it seems reasonable to presume that the precision in production of tempo ought to be closely linked to perception.

Earlier studies indicate that the just-noticeable difference (JND) for tempo detection is in the range of 2 %. This JND is about ten times the maximum tempo drift measured for professional drummers in a study by Dahl¹. The tempo drifts in this study were typically about 0.05 %/interval, or 0.25 ms/interval at 120 beats /minute (nominal beat separation 500 ms).

In comparison to other investigations of tempo detection, longer stimuli were used and smaller drift magnitudes were tested. While investigating perceptual threshold for tempo drift, we do not rule out the possibility that the internal “clock” can have an inherent tempo drift. In practice this means that some listeners will perceive that tempo is increasing when, in fact, it is decreasing, and vice versa.

Method

The method uses a modification of the method for Parameter Estimation by Sequential Testing (PEST). Several click sequences are presented to the listener in each test and depending on the listener’s response (correct or incorrect) the magnitude of the tempo drift is modified for the next presentation. Two correct responses in a row are required to assume that the response is correct. Thus the tempo drift converges towards the 75 % correct responses level.

Each session consist of several series running in parallel. At the start of each test session, each series is designated as either ‘increasing’ or ‘decreasing’. Because of the designation, the correct response to a series designated ‘decreasing’, is always “decreasing” – also when the physical drift is increasing. Thus, the physical drift of a series can shift sign and cross the zero-line as the response curves converge around a perceived isochronous tempo. The average endpoints across the ‘increasing’ and ‘decreasing’ series respectively, give a span of non-discriminable drift. This span was interpreted as twice the Just Noticeable Difference (JND),

centred around an internal reference; the Internal Drift (ID). Examples of the response series for two subjects with different ID and JND can be seen in Figure 1a & b.

Experiment

Seven subjects did three listening sessions of 40 minutes each. Each session consisted of six parallel series; three designated 'increasing' and three designated 'decreasing'. The nominal start tempo had a beat separation of 500 ms (120 beats/minute). The number of intervals per presentation was 10 (corresponding to 5 s). To minimize the recognition of an "absolute tempo" there some randomisation was applied to the initial nominal tempo for each stimulus. There was also an initial silence, randomized between 0.5 and 1 s.

Analysis and results

Figure 2 shows the individual and mean internal drifts for the seven subjects. The internal drift differs significantly between subjects, but each subject is consistent. There were no significant differences between sessions for any of the subjects.

The JNDs for the subjects are shown in Figure 3. The mean JND across the seven subjects was 0.27 % of nominal IOI, corresponding to a change of 1.35 ms per interval.

Conclusion

The found values for JND are small when comparing to previously reported estimates (e.g. Drake and Botte², Madison³). However, our results correspond to measured production data (Dahl¹, Madison³). The method also appears to be successful in estimating the internal drift (ID). This ID was consistent within subjects, but differed between subjects. Further investigations could shed light on how the internal drifts depend on the nominal tempo (cf Vos⁴).

Acknowledgements

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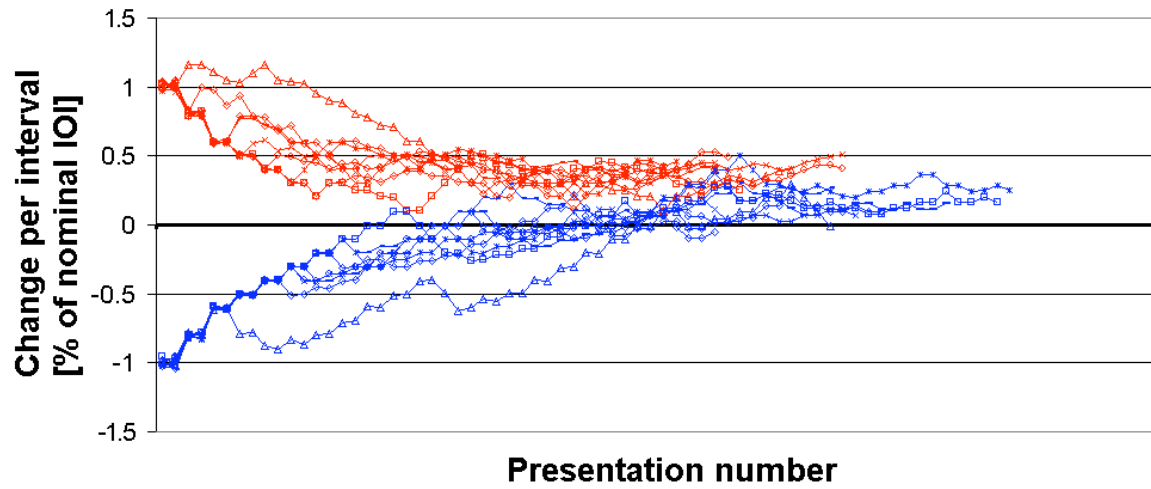
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FIGURES

Figure 1 (a) & (b). The response series for two subjects:

Subject AA (a) has an ID corresponding to a decreasing tempo and a small JND.



Subject GS (b) has an ID corresponding to a increasing tempo and a larger JND.

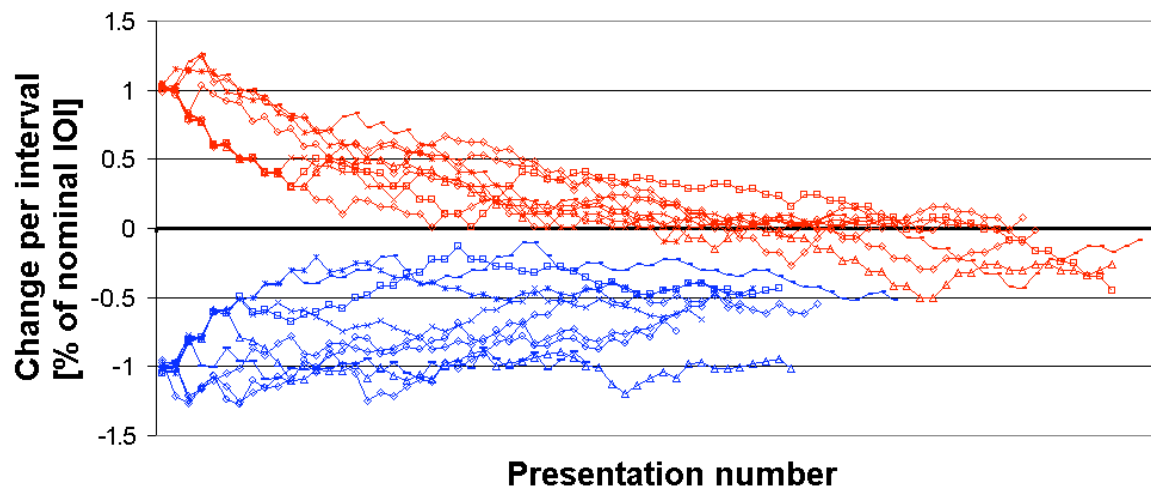


Figure 2. Individual and mean JND for the seven subjects. The vertical error bars indicate the standard deviation.

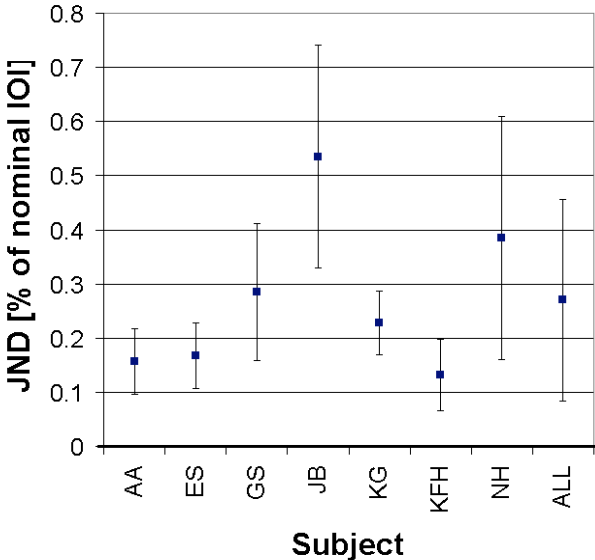


Figure 3. Individual and mean ID for the seven subjects. The vertical error bars indicate the standard deviation.

