Motor behaviour in drumming with different striking tools: Effects of tempo on control of rebound.

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1. AIM

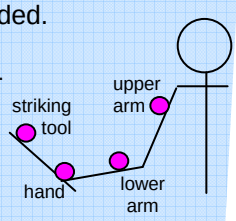
How do drummers adapt their playing to different playing conditions, i.e. different striking tools and/or tempi?

To investigate this, the movements of four drummers were recorded while playing single strokes with interleaved accents under differing playing conditions.

2. EXPERIMENT AND ANALYSIS

Four percussionists performed a rhythmic pattern with interleaved **accents every fourth stroke**. Using a motion tracking system, 3D displacement data of the **striking tool**, the players' **hand**, and **lower and upper arm** were recorded.

- Tempi: 116, 16, and 200 beats per minute.
- Striking tools: stick, mallet, and brush.
- Subjects S1 and S3 have their main experience from orchestral playing
- Subjects S2 and S3 are primarily drumset players

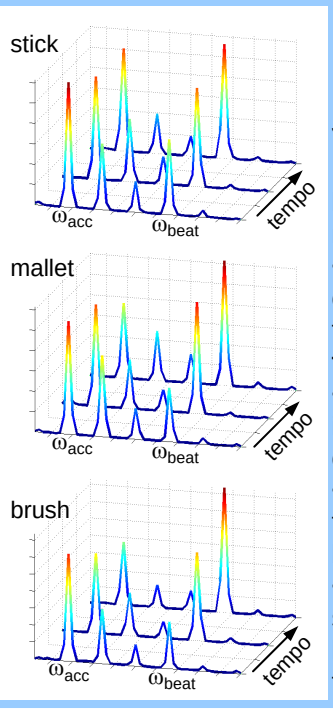


The displacement **time series** were **normalized** to unit variance and linear trends were eliminated. For each condition, **20 cycles** of each time series were combined into a single N-dimensional state vector (N = 4 subjects x 4 markers x 3 directions =48 for the over-all analysis) which was subjected to **Principal Component Analysis** (PCA).

3. RESULTS: ALL SUBJECTS

The analysis showed **two goal-related frequencies**: ω_{acc}, corresponding to the **accent** recurrent every fourth stroke, and ω_{beat} ,corresponding to the **played tempo**.

Eigenvalues ranged between 27- 37% (1st mode), 14-18% (2nd mode), and 8-12% (3rd mode). For mallet the values for the first three modes were consistently lower compared to the stick and the brush.



Spectral Projections

Both tempo and tool had large impact on the 1st mode (see figure)

- At **slow tempo, ω_{acc} dominated** the system's temporal evolution for all **three striking tools.**
- At **fast tempo, ω_{beat}** increased and became **dominant**.
- ω_{acc} decreased with tempo for mallet and brush, but not for stick.
- For the 2nd mode, the stick had stronger harmonics compared to the other tools.

- **Principle Component Analysis (PCA)** Method for data reduction. Data is transformed using a set of linearly independent vectors, or *modes*. Modes are ranked according to their contribution to the over-all variance. The contribution of a mode to the data set is quantified by its *eigenvalue*.

4. RESULTS: INDIVIDUAL ANALYSIS

In general, the individual PCA-analysis resulted in more **explained variance** by the first modes (ranging between 28-43% for the 1st mode). The effects of tempo and striking tool on modes varied considerably:

	S1	S3	S2	S4
strong ω_{acc}			dominates 1st **decreases** with **tempo**	dominates 1st
strong ω_{beat}	1st - 3rd in **all tempi** & tools, **more** for **mallet**	1st – 4th in **all tempi** & tools, **more** for **stick**	3rd & 4th **increase** with **tempo**	3rd & 4th **decrease** with **tempo**, up for stick
partials		prominent in 3rd & 4th	equal to ω_{acc} & ω_{beat} in 2nd	prominent

5. CONCLUSION

- The **over-all results** show a **"stiffening"** of the system with **increasing tempo**. The component related to the **accent influenced** the **stick** more than the other tools, indicating an **adjustment** to the **stronger rebound** after the accent for this tool.
- The component related to the **accent dominated** the system's temporal evolution at **slow tempi** for the **drumset** players (S2 and S4). For the **orchestral** players (S1 and S3) the component related to the **beats per minute** was important at all tempi.