Measuring altered movement patterns of musicians - Accuracy of a Motion Capturing System outside laboratory conditions

Nikolaus Ballenberger, Dirk Möller, Eduard Wolf, Christoff Zalpour
Background

• Use of *camera-based movement analysis* systems in medicine, kinesiology, biomechanics and in music health sciences

→ Identification of *altered/disturbed movement* patterns which lead to an *increased risk* of injury/illness for musicians (Davis, 1997; Dixon, 2011)

• Research project: “*Musikphysioanalysis*”

→ Do musicians with playing-related musculoskeletal complaints show altered movement patterns?
Background

• **high accuracy** of measurements under lab conditions (Everaert, 1998; Windolf, 2008)

• **Advantage**: Motion capturing systems are **not restricted** to lab use

• Measurement **under mobile conditions** in familiar/natural surroundings e.g. when rehearsing....

→ However, no data available of measurement accuracy out of lab
Aim of study

To investigate whether mobile use of a marker based motion capturing system impairs measurement accuracy by means of two “pragmatic” experiments (accuracy = absence of systematic and random error)
Methods: Experiment 1

_Wand_ swung in measurement volume (60 sec) in **three scenarios:**
- Out of lab (8m x 4m x 2.5m)
- Out of lab (5m x 3m x 2.5m)
- Lab (10m x 8m x 2.5m)

→ Compare measured distances to **true value** (600.8 mm)
Methods: Experiment 2

musician playing **chromatic scale** with „**marked**“ violin in in **three scenarios**:  
- Out of lab (8m x 4m x 2.5m)  
- Out of lab (5m x 3m x 2.5m)  
- Lab (10m x 8m x 2.5m)

**Comparison** to „**true**“ values ➔ under static conditions:  
➔ distances (true values)  
➔ Angles (true values)
Methods: Calculating measurement error

- Calculation of all possible distances/angles between all markers.
- Calculation of deviation from true value (measurement error) for each of the 9000 measurements for each marker separately.
- Processed by moving average.
Methods: Calculating measurement error

k denotes the number of markers m and n the number of measurements i

Deviation from true value of one single measurement = \( x_{mi} - true\ value_m \)

Total error of marker \( m \) \( TE_m = \frac{1}{n} \sum_{i=1}^{n} (x_{mi} - true\ value_m)^2 \)

→ Decomposition of \( TE_m \) into systematic and random error for each marker

Random error of marker \( m \) \( RE_m = \frac{1}{n} \sum_{i=1}^{n} (x_{mi} - \bar{x}_m)^2 \)

Systematic error of marker \( m \) \( SE_m = \bar{x}_m - true\ value_m \)

Overall error across all markers \( \rightarrow \) decomposition into: squared average random error of all markers and variance of systematic errors of all markers

\[ \sqrt{RE^2 + \frac{1}{k} \sum_{m=1}^{k} (SE_m - \overline{SE})^2 + SE^2} \text{ or } \sqrt{\frac{1}{kn} \sum_{m=1}^{k} \sum_{i=1}^{n} (x_{mi} - true\ value_m)^2} \]
Methods: Calculating measurement error (Graphical illustration)

Random error = dispersion around measured mean

Systematic error = mean deviation from zero (no deviation from true value)
Methods: Calculating measurement error (Graphical illustration)

**Total error:** pooling errors across all markers

**Random error** = dispersion around measured mean

**Systematic error** = mean deviation from zero (no deviation from true value)
Deviation (distance) from true value depending on experiment 1 with wand.
Deviation (distance) from true value depending (experiment 1 with wand)

Out of lab with large volume

- RE (random error): 0.47
- SE (systematic error): 0.49
- TE (total error): 0.68

Out of lab with small volume

- RE (random error): 0.16
- SE (systematic error): -0.12
- TE (total error): 0.21

Lab

- RE (random error): 0.26
- SE (systematic error): -0.49
- TE (total error): 0.55
Deviation (distance) from true value depending on scenario and marker (experiment 2 with violin)

Out of lab with large volume   Out of lab with small volume   Lab
Deviation (distance) from true value depending on scenario and marker (experiment 2 with violin)

No reduction in accuracy so far between lab and out of lab....

Out of lab with large volume  Out of lab with small volume  Lab
Deviation (distance) from true value depending on scenario and marker (experiment 2 with violin)

Out of lab with large volume  Out of lab with small volume  Lab

BUT
Deviation (distance) from true value depending on scenario and marker (experiment 2 with violin)

Out of lab with large volume

Out of lab with small volume

Lab
Deviation (distance) from true value depending on scenario and marker (experiment 2 with violin)

Out of lab with large volume  Out of lab with small volume  Lab
Deviation (distance) from true value depending on scenario and marker (experiment 2 with violin)

Out of lab with large volume
Out of lab with small volume
Lab

<table>
<thead>
<tr>
<th>Scenario</th>
<th>RE</th>
<th>SE</th>
<th>SD (SE)</th>
<th>Overall TE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large volume</td>
<td>0.25</td>
<td>-0.23</td>
<td>0.34</td>
<td>0.49</td>
</tr>
<tr>
<td>Small volume</td>
<td>0.21</td>
<td>-0.21</td>
<td>0.26</td>
<td>0.41</td>
</tr>
<tr>
<td>Lab</td>
<td>0.21</td>
<td>-0.50</td>
<td>4.16</td>
<td>4.19</td>
</tr>
</tbody>
</table>
Deviation (distance) from true value depending on scenario and marker (experiment 2 with violin)

Out of lab with large volume  Out of lab with small volume  Lab
Deviation (distance) from true value depending on scenario and marker (experiment 2 with violin)

<table>
<thead>
<tr>
<th>RE</th>
<th>SE</th>
<th>SD (SE)</th>
<th>Overall TE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>-0.23</td>
<td>0.34</td>
<td>0.49</td>
</tr>
</tbody>
</table>

Out of lab with large volume

<table>
<thead>
<tr>
<th>RE</th>
<th>SE</th>
<th>SD (SE)</th>
<th>Overall TE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.18</td>
<td>0.02</td>
<td>0.26</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Out of lab with small volume

<table>
<thead>
<tr>
<th>RE</th>
<th>SE</th>
<th>SD (SE)</th>
<th>Overall TE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.23</td>
<td>&lt;0.01</td>
<td>1.67</td>
<td>1.70</td>
</tr>
</tbody>
</table>

Lab
What is the problem?
What is the problem?
Merging of markers
no reduction of accuracy under mobile conditions but due to measurement volume
Deviation (distance) from true value depending on scenario and marker (experiment 2 with violin)

Out of lab (8m x 4m x 2.5m)
Out of lab (5m x 3m x 2.5m)
Lab (10m x 8m x 2.5m)
Discussion/Conclusion

• no loss of accuracy out of lab
• Large volume (long distance of cameras) leads to merging of close markers
• No conclusion about accuracy when markers are changing positions
  → however: no assessment of accuracy possible due to missing gold standard
• no guarantee of accuracy with calibration by wand
Discussion/Conclusion

Message:

• Measureing out of lab is without reducing accuracy
• BUT: be aware of optimal volume especially with close markers!
References


MUSICPHYSIO 2018
2nd World Congress on MUSICIAN’S PHYSIOTHERAPY

Lectures
Prof. Dr. Ulrik Roijezon (Lulea University, Sweden)
Posture, Motor Control & Performance
Robert Kuizenga (Counter Tenor, PT, Amsterdam)
Physiotherapy & Voice
Prof. Dr. Bronwen J. Ackermann (University of Sydney, Australia)
Musicians’ Physiotherapy: Past, Present and Future
Prof. Dr. med. Eckart Altenmüller (hmtm Hannover, Germany)
Movement Disorders in Musician’s: Differential Diagnosis and Treatment Options

Workshops
Ed Blake (Physio ED, London)
Orofacial and Neck Assessment & Management
Dr. Sonia Ranelli (Curtin University, Perth)
Hand and Upper Limb Problems in Musicians: Physical and Sensory Assessment in Musicians and Implications for Management
Dr. Jan Dommerholt (Bethesda, Baltimore)
Management of Myofascial Pain

...and many more

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