The Dynamics of Bilateral Tremor during Goal-Directed Pointing

Keogh, J., Morrison, S. & Barrett, R.
School of Physiotherapy & Exercise Science, Griffith University, Gold Coast

Introduction
Coordination can be viewed as the mastery of the redundant degrees of freedom (DF) used during movement (Bernstein, 1967). In postural pointing tasks, coordination may involve the coupling of adjacent limb segments in a compensatory arrangement, thereby reducing the number of DF needing to be controlled (Morrison & Newell, 2000). While many isotonic bilateral movements are characterized by a degree of bilateral (inter-limb) coupling, bilateral postural pointing tasks generally exhibit no significant inter-limb coupling, even though similar intra-limb relations are evident (Morrison & Newell, 1999). However, as task complexity increases, the level of bilateral coupling may also increase (Morrison & Newell, 1999). This may suggest that increased bilateral coupling may be a coordinative solution used to reduce the number of DF needing to be controlled in bilateral tasks. Therefore this study sought to address the effect of increasing accuracy requirements on the intra- and inter-limb relations during bilateral postural tasks.

Methods
Six subjects attempted to minimize limb tremor during three related movement tasks. The tasks involved either maintaining a postural pointing position (Pointing) or aiming at one of two different sized targets with a small lightweight laser pointer (Target 1 and Target 2). Target 1 and 2 consisted of a series of concentric circles of different radii (4 cm and 2 cm radius), respectively, and were positioned 5.5 m from the subject. Subjects held the laser pointers in each hand during all conditions, with the laser only being switched “on” during the targeting (aiming) tasks. The goal of the pointing task was to minimize oscillations of the index finger, while the goal of the aiming tasks was to keep the laser pointer emissions within the innermost circle of each target area. Eight 30 s trials were performed for each condition. Measures of limb tremor (using small lightweight uniaxial accelerometers), muscle (EMG) activity (from EDL and FDL), and target accuracy were recorded. Data analysis examined the principal time and frequency components of tremor, EMG and target accuracy.

Results & Discussion

Time Series
A significant reduction in the mean RMS tremor amplitude occurred as accuracy requirements increased (see Table 1). The decrease in tremor amplitude was unexpected as imposing accuracy requirements on unilateral postural tasks lead to significantly greater tremor amplitude (Morrison & Keogh, in press).

<table>
<thead>
<tr>
<th>Measure</th>
<th>Limb</th>
<th>Pointing (m.s^{-2})</th>
<th>Target 1 (m.s^{-2})</th>
<th>Target 2 (m.s^{-2})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finger</td>
<td>Right</td>
<td>0.23</td>
<td>0.18</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>0.24</td>
<td>0.18</td>
<td>0.20</td>
</tr>
<tr>
<td>Hand</td>
<td>Right</td>
<td>0.13</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>0.12</td>
<td>0.09</td>
<td>0.09</td>
</tr>
<tr>
<td>Forearm</td>
<td>Right</td>
<td>0.08</td>
<td>0.06</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>0.09</td>
<td>0.07</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Table 1: Mean RMS tremor amplitude as a function of task and limb segment.

Muscle activity in the EDL and FDL muscles was greater in the targeting than pointing tasks. This increase in muscle activity coincided with greater variability in targeting performance for Target 2 than the Target 1 (p < 0.001).
**Frequency Analysis**

Similar to unilateral multi-segment tremor studies, prominent frequency peaks for each segment were seen between 2-4 Hz and 8-12 Hz (Morrison & Newell, 1999, 2000) (see Figure 1 for a representative trial). The proximal-to-distal difference in tremor power (see Figure 1), is also consistent with previous reports (Morrison & Newell, 1999, 2000). As accuracy requirements increased, peak power at the finger decreased significantly (p < 0.0001). This contrasts with reports of unilateral targeting where a significant increase in the 8-12 Hz power was seen with increased accuracy demands (Morrison & Keogh, in press). However a decrease in the power of these peaks is consistent with the decrease in tremor RMS amplitude.

![Figure 1: Representative power spectral density multi-segment tremor plots for bilateral pointing.](image)

**Intra-Limb Coupling**

**Correlation**

Significant intra-limb correlations in pointing tasks were evident between the finger and hand (right limb: r = 0.72; left limb: r = 0.74), with no significant correlations between the hand and forearm (right limb: r = 0.10; left limb: r = 0.14). As accuracy requirements increased, these intra-limb correlations decreased for the finger and hand (right limb: r = 0.65; left limb: r = 0.60), and the hand and forearm (r = -0.13; left limb: r = -0.13).

**Coherence**

Significant intra-limb coherences were seen in pointing tasks between adjacent segments in both limbs between 1-7 Hz (r = 0.92-0.96) and 7-17 Hz (r = 0.77-0.92). As accuracy requirements increased, a significant decrease in intra-limb coherence between adjacent segments was observed between 1-7 Hz (p < 0.001), with no change between 7-17 Hz (p > 0.05). This was unexpected as previous studies have shown decreased coherence at both frequency bandwidths (Morrison & Newell, 2000).

**Inter-Limb (Bilateral) Coupling**

**Correlation**

No significant inter-limb correlations were seen in pointing tasks (finger–finger r = 0.03; hand-hand r =
As accuracy requirements increased, inter-limb relations increased at all segments (finger–finger $r = 0.10$; hand-hand $r = 0.14$; forearm-forearm $r = 0.10$).

Coherence
Similar to the inter-limb correlations, no significant coherence was seen between limbs for the bilateral pointing task at either 1-7 Hz or 7-17 Hz. As accuracy requirements increased, the degree of inter-limb coherence between contralateral fingers increased (see Figure 2).

As expected, significant levels of intra-limb coupling existed between segments in the bilateral pointing task, and this coupling was similar between limbs. The intra-limb coupling tended to decrease with increased accuracy demand similar to that for unilateral targeting tasks (Morrison & Keogh, in press). No significant inter-limb coupling existed in pointing tasks, although the level of inter-limb coupling increased as the task became more goal-directed. This was consistent with previous studies of bilateral tremor (Morrison & Newell, 2000) and suggests that increased bilateral coupling may simplify the coordination of complex bilateral tasks by reducing the number of DF needing to be controlled (Bernstein, 1967).

References

Acknowledgements
Thanks to Mrs Karen Smith for her invaluable assistance in data collection for this project, and to Mr Adam Corbett for designing the Labview data collection software.