Dr Mark Hollands

Don’t put a foot wrong!
walking and falling

- falls occur mostly during over-ground walking on even or uneven surfaces and result from trips or slips
  - i.e. inappropriate movement of the leg and/or placement of the foot

- vision is the only sense that tells us in advance where we should or should not step
where do we look when we walk?

• there is a strong relationship between looking and stepping

• are there age-related differences in sampling and using visual information and what are the implications for falls?
measurements

*Gaze* - high speed ASL 500 eye tracking system

Walking characteristics - 13 camera Vicon MX motion analysis system

<table>
<thead>
<tr>
<th></th>
<th>Young adults</th>
<th>Low-risk older adults</th>
<th>High-risk older adults</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Target1</td>
<td>Target2</td>
<td>Target1</td>
</tr>
<tr>
<td>Interval between saccade onset and toe-off (ms)</td>
<td>0.28 ± 0.09</td>
<td>0.56 ± 0.33</td>
<td>1.22 ± 0.65&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total fixation time (s)</td>
<td>0.72 ± 0.21</td>
<td>0.91 ± 0.40&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.65 ± 0.52&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Medio-lateral foot placement (mm)</td>
<td>15.66 ± 11.63</td>
<td>20.04 ± 19.28&lt;sup&gt;c&lt;/sup&gt;</td>
<td>−2.09 ± 11.64&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Medio-lateral foot variability (mm)</td>
<td>8.95 ± 2.53</td>
<td>9.53 ± 2.62</td>
<td>10.53 ± 3.95</td>
</tr>
<tr>
<td>Anterior–posterior foot placement (mm)</td>
<td>−32.86 ± 29.39</td>
<td>−35.52 ± 24.40&lt;sup&gt;c&lt;/sup&gt;</td>
<td>−24.97 ± 23.67&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Anterior–posterior foot variability (mm)</td>
<td>19.02 ± 4.84</td>
<td>17.62 ± 4.39</td>
<td>23.57 ± 4.25</td>
</tr>
<tr>
<td>Step length (mm)</td>
<td>662.55 ± 78.26</td>
<td>690.39 ± 61.82&lt;sup&gt;c&lt;/sup&gt;</td>
<td>661.42 ± 113.12</td>
</tr>
<tr>
<td>Step width (mm)</td>
<td>165.81 ± 67.09</td>
<td>178.27 ± 43.75&lt;sup&gt;c&lt;/sup&gt;</td>
<td>192.79 ± 40.95&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Walking velocity (m s&lt;sup&gt;−1&lt;/sup&gt;)</td>
<td>1.21 ± 0.16&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>1.15 ± 0.23&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.79 ± 0.14&lt;sup&gt;a,b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Significantly (p < 0.05) different from young adults.
<sup>b</sup> Significantly different from low-risk older adults.
<sup>c</sup> Significantly different from Target1.
differences between young, older adults and older adult fallers in gaze and stepping behaviour

- older adults (particularly high-risk) look at stepping targets much sooner than young adults and stay looking for much longer
- high-risk older adults show increased variability in mediolateral foot positioning
why do older adult fallers show altered visual behaviour?

- cognitive changes?
  - anxiety/fear of falling?
  - attentional deficits?
  - changes in executive functioning?

- changes in visuomotor processing?
  - more time needed fixating target in order for CNS to process visual info and/or transform it into appropriate stepping movements?
The contribution of visuomotor decline to falls in older adults during adaptive locomotion

Aims

systematically test if high-risk older adults require more time visually fixating targets than low-risk older adults and younger adults to ensure accurate stepping
experimental paradigm
experimental design

• participant groups
  - young adults (10)
  - low-risk older adults (10)
  - high-risk older adults (10)

• target conditions
  - neutral (central) targets
  - wide targets

• gaze behaviour (time fixating a target prior to foot landing on (or near) it)
  - 0 to 1 second
  - 1 to 2 seconds
  - 2 to 3 seconds
predictions

constraining the timing of LED illumination will have a detrimental effect on older adults stepping performance

high-risk older adults will require more time fixating the LEDs in order to step as accurately as low-risk older adults and younger adults

high-risk older adults will show greater errors when stepping to wide targets
how much time is needed looking at a target for accurate stepping?

Interval between target fixation and foot contact (s)

M/L constant stepping error (mm)

-1.0 to 0  -2.0 to -1.0  -3.0 to -2.0

central wide central wide central wide

narrow

young
how much time is needed looking at a target for accurate stepping?

**Normal size**

- **Interval between target fixation and foot contact (s)**

**Wide**
- M/L constant stepping error (mm)

<table>
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<tr>
<th>Interval</th>
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<th>LROA</th>
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<tr>
<td>-1.0 to 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-2.0 to -1.0</td>
<td></td>
<td></td>
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<tr>
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**Narrow**
- M/L constant stepping error (mm)

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**Legend**
- young
- LROA
how much time is needed looking at a target for accurate stepping?

significant interaction between time and group
\[ F_{(4,54)} = 2.7, \ p<0.05 \]
results summary
m/l stepping error

• high-risk older adults significantly less accurate than other groups (especially to wide targets)

• all groups show increase step width errors when receiving less than one second fixating target (especially high-risk older adults)
how much time is needed looking at a target for consistent stepping?

![Graph showing M/L variable stepping error (mm) vs. Interval between target fixation and foot contact (s). The graph compares 'central' and 'wide' conditions at intervals of -1.0 to 0, -2.0 to -1.0, and -3.0 to -2.0 seconds. The data points are represented by bars, with error bars indicating variability. The graph is labeled 'young.'
how much time is needed looking at a target for consistent stepping?
how much time is needed looking at a target for consistent stepping?

interaction between time, target position and group $F_{(4, 54)} = 3.3, P < 0.05$
results summary
constant m/l stepping errors

• high-risk older adults significantly more variable in m/l foot placement than other groups

• all groups show increased m/l foot placement variability when receiving less than one second fixating target (especially high-risk older adults)
how much time is needed looking at a target to avoid missing it completely?
how much time is needed looking at a target to avoid missing it completely?
how much time is needed looking at a target to avoid missing it completely?

![Bar chart showing the frequency of missed steps (%) for different intervals between target fixation and foot contact (s) for young, LROA, and HROA participants.](chart.png)

- **Interval between target fixation and foot contact (s):**
  - Central: -1.0 to 0 s
  - Wide: -2.0 to -1.0 s
  - Central: -3.0 to -2.0 s

- **Frequency of missed steps (%):**
  - Young: [chart data]
  - LROA: [chart data]
  - HROA: [chart data]
results summary
missed targets

• young adults only missed targets when received less than 1 second fixation

• older adult groups missed progressively more targets when given less time to fixate them
is there a threshold of target fixation duration below which step width errors start to accumulate?

Central targets
is there a threshold of target fixation duration below which step width errors start to accumulate?

Central targets

![Graph showing cumulative sum of M/L stepping errors (m) vs. interval between target fixation and foot contact (s). The graph compares young and low-risk groups with different target fixation durations.](image)
is there a threshold of target fixation duration below which step width errors start to accumulate?

Central targets

- Cumulative sum of M/L stepping errors (m)

- Interval between target fixation and foot contact (s)

- young
- low risk
- high risk

- wide
- narrow
is there a threshold of target fixation duration below which step width errors start to accumulate?

Wide Targets

Cumulative sum of M/L stepping errors (m)

Interval between target fixation and foot contact (s)

- young

narrow
is there a threshold of target fixation duration below which step width errors start to accumulate?

Wide Targets

Cumulative sum of M/L stepping errors (m)

Interval between target fixation and foot contact (s)
is there a threshold of target fixation duration below which step width errors start to accumulate?

Wide Targets

Interval between target fixation and foot contact (s)

Cumulative sum of M/L stepping errors (m)

- young
- low risk
- high risk

narrow
discussion

- older adults (particularly high-risk) require longer fixating a target in order to step accurately
- stepping inaccuracies constrained to errors in step-width rather than step length
- implications for increased prominence of sideways falls in older adult populations
conclusions

• differences between young, low-risk and high-risk older adults in eye movement behaviour during walking
• likely reflect age-related changes in time required for effective visuomotor planning and/or biomechanical factors
• implications for diagnosis of falls risk, elucidation of underlying neurophysiological and psychological mechanisms and rehabilitation
what next?

• to what extent can individuals adjust stepping trajectories during swing?
  - are there age- and risk of fall-related differences

• are there age-related differences in the biomechanics of stepping wide?
acknowledgements

• School of Sport and Exercise Sciences
• Dr Graham Chapman
Symposium on Gait, Posture and Balance: Function, Dysfunction and Rehabilitation

School of Sport and Exercise Sciences
University of Birmingham
27th and 28th May 2008

Keynote Speakers

CNS control of Posture and Balance
Professor Richard Fitzpatrick
(Prince of Wales Medical Research Institute, New South Wales, Australia)

CNS control of Gait
Professor Jacques Duysens
(Department of Rehabilitation, Radboud University Nijmegen Medical Centre, The Netherlands)

Gait Recovery in Neurological Rehabilitation
Dr Cordula Werner
(Department of Neurological Rehabilitation, Charité University Hospital, Germany)

http://gaitandposture.googlepages.com/home