SMART rehabilitation and motion tracking systems to support rehabilitation of people with stroke

Dr Nigel Harris, Royal National Hospital for Rheumatic Diseases
on behalf of the EPSRC EQUAL SMART rehabilitation consortium

http://hsc.shu.ac.uk/smart/
Consortium and Partners

- University of Bath
- RNHRD
- Sheffield Hallam University
- University of Essex
- University of Ulster
- Stroke Association
- Bath Sport and Exercise Science
- Head Injury Unit RNHRD
- Sheffield Teaching Hospitals / Chippenham Stroke Unit
- RUH Bath Care of the Elderly

‘To examine the scope, effectiveness and appropriateness of systems to support home-based rehabilitation programmes for older people and their carers’
Why do people go into care?

- **Impact of Stroke @ 6 months**
  - 49% need help bathing
  - 31% need help dressing
  - 33% need help with feeding

- **Locomotor disability and physical impairment account for 65% of those in care.**

More effective rehabilitation will help people remain at home.

DOH 2000
Tony Rudd Guys & St. Thomas
Benefit of home rehabilitation

- Cochrane Review Issue 1 2004
  Therapy based rehabilitation services for Stroke patients at home


- Dynamic or isometric resistance training improves function and decreases pain in OA (Topp et al Arch Phys Med Rehab 2002).
Rehabilitation – some issues

• Rehabilitation traditionally hands on – technology that can enable and support rehabilitation is not being exploited.

• Repetition is primary contributor to functional recovery but compliance is poor.

‘As I get older I am inclined to do less of the things I ought to do and more of the things I want to do.’

Quality and skill acquisition are important!
Devices available for motion tracking and rehabilitation

- Switches (Pedometer, Oddstock FES)
- Gyroscopes (angle / rate of turn)
- Accelerometers (velocity)
- Radio frequency, magnetic field
- Video systems
  - Passive (Vicon) or Active (CODA)
- Robot arms (MANUS/MIME)

Active video motion capture
Charnwood Dynamics *coda*
CODA marker placement for gait analysis

- Sac.Wand [1]
- PSIS [2]
- ASIS [3]
- Ant.Fem. [6]
- Post.Fem. [5]
- Knee [9]
- Post.Tib. [7]
- Ant.Tib. [8]
- Ankle [10]
- Toe [12]
- (Hip [23])
Single axis accelerometer

Activpal monitoring of additional in-patient sit to stand practice

Activity summary for 216CF104 May
activPAL serial number: 216CF104
Start Time: 01:42:01 PM 19-May-05
Stop Time: 02:11:31 PM 19-May-05
Elapsed Time: 00:29:30

TIME (h:m:s)
- Sitting/Lying: 00:23:34 (79.9%)
- Standing: 00:05:54 (20%)
- Stepping: 00:00:02 (0.1%)

TOTAL NUMBER OF STEPS: 2
- Energy Expenditure: 0.5 MET.h
- Upright Events: 32
- Seated/Lying Events: 31

Bratton et al, SRR July 2005
How much extra practice?
McRoberts MiniMod Accellerometer

- 3 Axis accelerometer
- Data stored on SD memory
- Download, artifact rejection
- Data analysis
- McRoberts gait test
- Assessment of sit to stand performance after Pain Management.

www.dynaport.nl
Is the technology appropriate?

1. Review literature
2. Identify specific rehabilitation interventions
3. Generate rehab movement templates
4. Present scenarios to focus groups
5. Establish design specification
6. Evaluate prototype device with users
Basic types of intervention

- Sit to stand
- Step forward with affected limb
- Reach forward and return upper limb
- Hand to mouth and return (with object)
Reference data - functional upper limb activity following stroke

- Pilot investigation of older adult participants
- 1 trial of cyclic drinking activities
- Self-paced repetition

- 3D motion
- Linear and angular measures
- Time derivatives of linear and angular measures
- Joint and segmental measures

Hammerton & Gittoes 2005
UPPER BODY MODEL

4 segment model
13 segmental markers •
4 supplementary markers •

Marker | Marker name
--- | ---
1 | C3
2 | C7
3 | T12
4 | Acromian
5 | UArm wandP
6 | UArm wandD
7 | Lateral epicondyle
8 | LArm wandP
9 | LArm wandD
10 | Radial styloid
11 | Ulna styloid
12 | 3mcp
13 | 5mcp
## TEMPORAL CHARACTERISTICS OF DRINKING

<table>
<thead>
<tr>
<th></th>
<th>Non-Stroke</th>
<th>Stroke</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cycle duration (s)</strong></td>
<td>3.28</td>
<td>3.76</td>
</tr>
<tr>
<td><strong>Upward phase (s)</strong></td>
<td>1.63 (49.7%)</td>
<td>1.97 (52.4%)</td>
</tr>
<tr>
<td><strong>Downward phase (s)</strong></td>
<td>1.60 (48.9%)</td>
<td>1.67 (44.2%)</td>
</tr>
</tbody>
</table>

Hammerton & Gittoes 2005
Elbow Flexion / Extension

Mean range = 91.8 °

Non-stroke

Mean range = 59.5 °

Stroke

Trunk (T12) Deviation

Non-stroke

Stroke
KEY MEASURES

- Cycle durations
- Phase durations (e.g. cup to mouth)
- Range of joint motions (elbow flexion/extension)
- Segment deviation (trunk motion)
- Interaction of joint actions (coordination)
- End effector peak velocity

How much data, real time or summary?
Experience of rehabilitation

Anticipated benefits
- More help
- More effective rehab
- Seeing measurable results
- Reliance on services

Rehab requirements
- Adaptable to a variety of needs
- Upper limb function
- Walking Balance

Role of Rehabilitation
- Professional
- Remote monitoring
- Range of levels of support
- Role as motivator

Carer's Role
- Lack of expertise
- Partnership in rehab
- Encouraging independence
- Conflict

Practical Issues
- Ease of application
- Ease of use
- Nature of user feedback
- Support in using device
- Availability of device
- Support/maintenance

Psychological issues
- Cognitive and Motivation
- Value of feedback in motivation
- Self esteem
- Coping with home rehabilitation

McNair and Islam 2005
MT9 motion tracking system (MTS)

<table>
<thead>
<tr>
<th></th>
<th>Rate of Turn [deg/s]</th>
<th>Acceleration [m/s²]</th>
<th>Magnetic Field [mGauss]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dimensions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Full Scale</strong></td>
<td>[units]</td>
<td>+/- 900</td>
<td>3</td>
</tr>
<tr>
<td><strong>Linearity</strong></td>
<td>[% of FS]</td>
<td>0.1</td>
<td>3</td>
</tr>
<tr>
<td><strong>Bias stability</strong></td>
<td>Compensated [units 1σ]</td>
<td>5</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Uncompensated [units per °C]</td>
<td>1</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>Scale factor stability</strong></td>
<td>Compensated [% 1σ]</td>
<td>-</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Uncompensated [% per °C]</td>
<td>0.15</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Noise</strong></td>
<td>[units RMS]</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td><strong>Alignment error</strong></td>
<td>[deg]</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td><strong>Bandwidth</strong></td>
<td>[Hz]</td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

**Physical Specifications**
- Interface: Serial (RS-232 max 460Kbps)
- Operating Voltage: 5.5 V [adapter available]
- Supply Current: 40 mA
- Ambient Temperature: 0°C - 55°C
- Operating Range: 39 x 54 x 28 mm (W x L x H)
- Weight: 35 g
MT9 motion tracking system

MTS evaluation with CODA

Fig. 1. Kinematics of a human forearm (the fixed point is the elbow joint).
Motion Tracking System (MTS)

1. MTS built into bean bag / hat or clothing
2. Record target manoeuvre with therapist
3. Patient replicates the movement
4. System records data (quality and quantity)
5. Data downloaded to base station
6. Feedback to patient and carers
7. Feedback to HCP’s
Barriers to the use of technology by older users

- Negative self image
- Lack of understanding of technology
- Lack of trust in technology
- Operational anxiety following a bad experience

Alan Newell, University of Dundee
Project time table
(where are we ?)

- Reference data
- Focus groups (hardware and user interface)
- Evaluation of prototype
- Pilot studies on hospital patients
- Home based trials (January 2006)
- Evaluate performance - users and HCP’s

This work finishes November 2006
Consortium and Partners

- University of Bath
- RNHRD
- Sheffield Hallam University
- University of Essex
- University of Ulster
- Stroke Association
- Bath Sport and Exercise Science
- Head Injury Unit RNHRD
- Sheffield Teaching Hospitals / Chippenham Stroke Unit
- RUH Bath Care of the Elderly

http://hsc.shu.ac.uk/smart/