Healthcare Technologies at the Centre for Sports Engineering Research

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Functional Electrical Stimulation

- Used to counteract foot-drop following stroke or multiple sclerosis
- In use since 1960s, recently becoming more popular and clinically accepted.
Electrode location

- One surface electrode is used to stimulate both the deep and superficial branches of the common peroneal nerve – control dorsiflexion and in/eversion. Second electrode is placed over tibialis anterior.
- 40% of stroke patients required help with donning and doffing.
- Difficulty in locating the correct electrode site is the principal reason (after improvement in mobility), for discontinuing FES treatment.
Commercial systems

Odstock Pace  Walkaide  Bioness

All use single electrodes, precisely located
Steerable Virtual Electrodes
Array Functional Electrical Stimulation

In collaboration with Medical Physics, Sheffield Teaching Hospitals.

- Worlds smallest surface 64 channel stimulator
- Uses wireless accelerometer mounted on foot to detect magnitude and direction of foot response.
- First reported automated clinical setup of drop-foot stimulation.
- Shown to be similar to clinician-setup, worse than patients’ own setup for speed, better for foot position.
- Currently being assessed in a home trial.

Automated setup of functional electrical stimulation for drop foot using a novel 64 channel prototype stimulator and electrode array: Results from a gait-lab based study Heller et al. Medical Engineering & Physics in press.
‘Clinical trial - ShefStim’ – a 64 channel stimulator

- Traditional anode
- 64 channel array cathode
- Conventional footswitch
- Stimulator worn on patient’s leg
- Cable to PC (for setup only)
Setting-Up ShefStim I

- Stimulator mounted on the leg
- Electrode array in fixed position relative to head of fibula (for consistency)
- Anode applied over tibialis anterior
- Stimulation synchronised with walking via a footswitch
Setting up Sheffstim II

- Foot movement detected by means of electromagnetic movement sensor (accelerometer in final version)
- Three stage algorithm to find location
  1. Quickly find the intensity to start searching
  2. Use twitch stimulation to quickly find candidate sites
  3. Slowly ramp candidate sites, use a cost function to identify best location (based on intensity, foot response magnitude and direction)
Cost function
Clinical Trial

- Ten participants with stroke (ages 53–71 years) and 11 with MS (ages 40–80 years)
- Performed two walks of 10 m for each of the following conditions: own setup, clinician setup, automated setup and no stimulation
- Outcome measures were walking speed, foot angle at initial contact and the Borg Rating of Perceived Exertion
Results

- Mean walking speed with no stimulation was 0.61 m/s
- All FES setups significantly increased speed relative to this (AS $p < 0.05$, PS $p < 0.01$, CS $p < 0.01$)
- The mean reported time for the participants to set up their own stimulators at home was 11.0 min.
- The mean setup time for AS was 5.9 min, with a range from 2.6 to 8.8 min
Mean Dorsiflexion

Stance Phase

Swing Phase

Dorsiflexion (Degrees)

% Gait Cycle

Clinician

No Stim

ShefStim

Subject
Mean Foot Inversion

-5 0 5 10 15 20

0 10 20 30 40 50 60 70 80 90 100

% Gait Cycle

Inversion (Degrees)

Clinician
No Stim
ShefStim
Subject

Stance Phase
Swing Phase

Mean Foot Inversion
Other Uses – Upper limb stimulation

- Functional use as a neuro-prosthesis – requires sophisticated control strategy.
- Therapeutic use – rehabilitation training – focussed, functional and frequent.
- Control through contra-lateral limb movement (bimanual) and Kinect?
- May require augmentation through mechanical arm supports (powered or passive robot exoskeleton)
Other Uses – facilitating motor plasticity

Motor-cortex plasticity may be facilitated by transcranial stimulation of the motor-cortex, magnetically (TMS) or by passing a current directly through the cranium. Due to safety, convenience, and expense, these techniques are not suitable for uncontrolled application outside the laboratory.

Ridding and co-workers have shown that similar plasticity effects can be achieved by simultaneously stimulating two motor points with particular temporal patterns, a technique which is much more practical for use outside the lab.

Sensory Barrage Stimulation
Sensory Barrage Stimulation II

Potential application in reducing motor loss in acute stroke through intensive sensory stimulation.

Potential application in facilitating motor learning in other domains requiring acquisition of complex motor skills (e.g. sports, music).

Synergies with stochastic resonance?
Second lives for the third age: motivating rehabilitation in virtual environments

Ben Heller – project management and Physical Interface
Breda Beban – Creative direction
Kerry McSeveny – analysis of user behaviour
Katarzyna (Kasia) Machaczek – motivation
Ricard Gras (Interactiva) Second Life implementation, machinima
Ismail Mubarak – assistance and recruitment
Ann Light - (unfunded support)
The Chief Medical Officer states*:

A growing body of evidence suggests that diseases and conditions which are the primary cause of loss of function and independence in later life are preventable and physical activity can play an important part. Preventive effects arising from regular physical activity in older age are at least as strong as those found in middle age for all-cause mortality, cardiovascular disease, and type 2 diabetes.

*Department of Health At least five a week: Evidence on the impact of physical activity and its relationship to health 2004
Barriers to participation

- Health issues
- Environmental conditions
- Financial hardship
- Lack of social support
- Poor provision for specific cultural needs (e.g. single-sex sessions)
- Motivational barriers
- Consequently, only a minority of older people meet recommended levels of physical activity (Department of Health Better Health in Old Age 2004)
Global Context - Falls

- Increased likelihood of falling with age
- Affects not just frail, but also independent ‘well’ elderly
- Leading cause of injury-related hospitalisation in this population
- *Fear of falling* leads to reduced activity
- long-term adherence to exercise programs is imperative to reduce fall risk. *(Vogler et al. 2012)*
Exercise works – but you have to do it

**Targeted** rehabilitation through **active participation** and engagement in **contextually-appropriate** **repetitive** and **intensive** movements (e.g. Otago programme) shown to promote recovery

Exercises completed individually at home, can be tedious => problem with motivation.

Only effective with good compliance

Computer games can provide a controlled, safe and challenging stimulus for rehabilitation. **BUT most** computer games not suited to an older clientele.
Virtual worlds/ metaverses

Combination of computerised balance rehabilitation with virtual worlds\(^1\) provides possibility of rich age-appropriate scenarios and socialisation.

\(^1\)A **virtual world** is a computer-based simulated environment intended for its users to inhabit and interact via **avatars**. Some, but not all, virtual worlds allow for multiple users. Well-known virtual worlds include Second Life (Linden Labs) and World of Warcraft (Blizzard)
Second Lives for the Third Age - philosophy

AGE APPROPRIATE ACTIVITIES IN SECOND LIFE

motivator

MENTAL HEALTH BENEFITS

PHYSICAL HEALTH BENEFITS

enabler

PHYSICAL USER INTERFACE
Engineering for life study: Second Lives for the Third Age

Pilot funding to:

• Explore older peoples’ opinions and expectations of virtual worlds.

• Develop an age-appropriate, safe environment in the virtual world

• Develop a whole-body physical interface to allow rich interaction without requiring mouse or computer skills.
Things you miss or would like to do

- Going dancing at the local ballroom – getting dressed up to go out – tango, waltz etc., leave shoes at the cloakroom and put on "dancing shoes", silver ball, big band – meet boys!
- Swimming
- Sailing
- Horse riding
- Fishing (very popular sport for men)
- Running downhill really fast like kids do
- Sex
- Climbing trees
- Gardening – suggested possibility of "virtual garden" (to include pruning, weeding, hoeing, planting, watering, nurturing)
- Running a marathon
Travel

- Visit space (or sites of "space race", Cape Kennedy, Russia etc).
- Visit periods from history, e.g. 1920s and 30s – music, Art Deco etc., Victorian era shopping (perhaps real shopping via internet, actual gain)
- visit virtual museums
- Flying an aeroplane (was in Air Force when younger, but had to do ground job due to colour blindness)
- Travel (came up a lot) – problems with getting insurance to travel abroad when older – would like to revisit places, or see new ones – 18th Century "grand tour" of Europe, Grand Canyon
- Cycling through Staffordshire countryside (where she grew up – would like to feel ‘free as a bird’)
- Cycling or driving through interesting environments, to meet people
- Walking around streets of city (Glasgow) – lacks stamina to do that now – visiting parks, churches, galleries along the way
• **Role play** - Play the leading role in an opera
• **Socialisation**
  – Being with friends
  – Touching and being touched by another human being
  – Pets (virtual dog to take for walks)
• **Famous people** - Meet Elvis
Evaluation

4 older users - two women, two men (Somali)
Used both conventional and physical user interfaces
Opinions sought by interview
• Which bits did you enjoy the most?
• I think the flying bit
• The flying, why do you think that is?
• I just sort of feel as if I was flying as well
• Is there anything that you'd like to have been able to do in the garden that you couldn't?
• I can't think of anything no, I mean I walked round the garden, I flew round the garden, and I danced in the garden you know, um... well I suppose if I could pick some of the flowers, you know, and as I said before if you'd got an allotment in the garden to grow vegetables.
• So if you were to meet your grandchildren in Second Life, what kind of things do you think you'd like to do?

• Well I'd still like to hear ___ play his clarinet, and perhaps we could have a bandstand. And ___ a football pitch, he'd like that. And ___ a netball pitch, you know. And you could just go and watch quite easily.

• You could even join in if you wanted to

• Yeah, that's right, you could couldn't you. Yeah, I hadn't thought of that

• Do you think you'd enjoy that?

• Oh I'm sure I would, yes. Netball, I used to play when I was younger, and that would be good.

• You can even do concerts and things in Second Life

• You could play in the concert in the orchestra!
Results

• Users enjoyed the experience, could learn most gestures quickly and could see potential usefulness.

• Users had difficulty with speed of movement in Second Life, particularly turning.

• The simplest, most directly mapped movements were preferred (jump, wave, punch)

• The link between physical movement and avatar movement wasn’t always understood

• Social side was very important
Follow-on study

- Examining more participants
- A more open set of activities (participant led)
- Single and social dyads.
Implications

• Potentially improve quality and quantity of rehabilitation exercise whilst reducing cost.

• Potential additional benefits due to social and cognitive engagement as well as physical exercise => need to involve multiple practitioners.

• IT and organisational issues for delivery