FES-UPP: A novel functional electrical stimulation system to support upper limb functional task practice following stroke

Paul Taylor
The upper limb following stroke

- Around 85% of people with stroke have upper limb impairments on admission;
- Upper limb therapy in hospitals is costly to deliver, stays are short and hence therapy dose is low;
- ESD and community rehabilitation offer longer term treatment, but dose of therapy delivered remains low;
- Perhaps unsurprisingly, >50% of people with stroke have to manage the reality of life with upper limb impairments.

Functional electrical stimulation

• Well-established technique to generate force in weak or paralysed muscle(s), coordinated in such a way to support functional tasks;

• Growing evidence to support its use, but efficacy of current systems likely limited by:
  o Number of channels;
  o Opportunity for voluntary control over stimulation timing/intensity;
  o Provision of person & task-specific feedback;
  o Range of activities which can be supported.

• “There’s no F in FES” in clinical practice. Limited to exercise stimulation

## The Ten Principles of Motor Plasticity
*(Kleim and Jones, 2008)*

<table>
<thead>
<tr>
<th>Principle</th>
<th>Description</th>
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<tbody>
<tr>
<td>1. Use it or lose it</td>
<td>Failure to drive specific brain functions can lead to functional degradation.</td>
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<td>2. Use it and improve it</td>
<td>Training that drives a specific brain function can lead to an enhancement of that function.</td>
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<td>3. Specificity</td>
<td>The nature of the training experience dictates the nature of the plasticity.</td>
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<td>4. Repetition matters</td>
<td>Induction of plasticity requires sufficient repetition.</td>
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<td>5. Intensity matters</td>
<td>Induction of plasticity requires sufficient training intensity.</td>
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<td><strong>6. Time matters</strong></td>
<td>Different forms of plasticity occur at different times during training.</td>
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<td><strong>7. Salience matters</strong></td>
<td>The training experience must be sufficiently salient/relevant to produce plasticity.</td>
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<td><strong>8. Age matters</strong></td>
<td>Training-induced plasticity occurs more readily in younger brains.</td>
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<td><strong>9. Transference</strong></td>
<td>Plasticity in response to one training experience can enhance the acquisition of similar behaviours.</td>
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<td><strong>10. Interference</strong></td>
<td>Plasticity in response to one experience can interfere with the acquisition of other behaviours.</td>
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The Purpose of the FES-UPP System

• Provide an FES system that assists the practice of functional tasks
  • Practice tasks that can not be practices without assistance
  • Enable “mass practice” to increase overall therapy dose
• Maximise therapy while improving the efficiency of the therapists time

The aim of the Study

• Demonstrate that tasks can be performed better or in greater quantity with FES assistance
  • Videoed tasks will be assesses by assessors blinded to weather FES is on or off
Study details

- 3 sites
  - Salford Royal Hospitals Trust Stroke Unit
  - Bury ESD and Community Rehabilitation Team
  - Salisbury (recruited from stroke unit, treated by OML)
- 25 sub-acute, 5 chronic
- Selection criteria:
  - Confirmed Stroke
  - Any upper limb disability
  - Over 18
  - Able to give consent
  - Standard FES contraindications
  - Confounding medical conditions excluded
Neutral \rightarrow \text{Reach for object} \rightarrow \text{Sweep back}

- \text{Anterior deltoid & triceps (Wrist extensors)}
- \text{Biceps (Wrist extensors)}

- \text{Button press?}
- \Delta \theta > 30^\circ? \Rightarrow \text{Max}
- \Delta t > 3 \text{ sec.}?

- Forearm extensors
- Threshold

- Neutral \rightarrow \text{Reach for object} \rightarrow \text{Sweep back}
Select a task from the library or create one from scratch

Up to 5 phases plus Neutral
Tasks are broken down to phase
Each phase can have different muscles and intensities
Set the operating stimulation intensity range

- Max current at 50% pulse width
- Minimum pulse width at set current sufficient to cause minimum contraction (Threshold)
Choose sensors you want to use and test responses
Set parameters for each phase for each muscle
• Pulse with
• Ramp time
• Delay

Practising the task
• Progressing through the phases using a button press
• Used to train the system to know what angles are needed to auto trigger the movement
Choose transition rules

• What causes the move to the next phase?
  • Time
  • Button press
  • Change in angle
    • Which sensor?
    • Which angle?
  • Combinations of the above (OR, AND)

The system can suggest appropriate angles for triggering a transition, bases on practice in stage 3.
Add instruction to the screen
• Standard
• Custom
• One instruction for each phase
Feedback
• Count repetitions
• Feed back of trunk angle to avoid leaning forward
Session screen

Phase

Instruction to user

Progress through phase
Can be time or angle

Feedback of torso angle

Reach to target with a long arm

Progress

OK
Too much torso lean forward
Feedback to user

Well done!

Brush coins: 5 reps

Continue
Participant Z08 (chronic 18 months) without FES
Participant Z08 (chronic 18 months) with FES. Sequence initiated by shoulder abduction using a forearm sensor.
Participant Z02 (6 weeks post stroke) without FES.
Participant Z0 (6 weeks post stroke) with FES. Sequence initiated by button press and progressed by a combination of forearm angle change, time outs and button presses.
Participant Z06 (9 years post stroke) without FES.
Participant Z06 (9 years post stroke) with FES. Sequence initiated button press and progressed using time-outs. Note shoulder sensor used to provide feedback on shoulder elevation to improve quality of movement.
Conclusions and next steps

• Formal results not analysed yet
• The system appears to work!
• Some improvements could be made to speed up use and improve usability
• Quite time consuming for the clinician
• Simplification needed for independent home use.
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