Low-cost personalised instrumented clothing with integrated FES electrodes for upper limb rehabilitation

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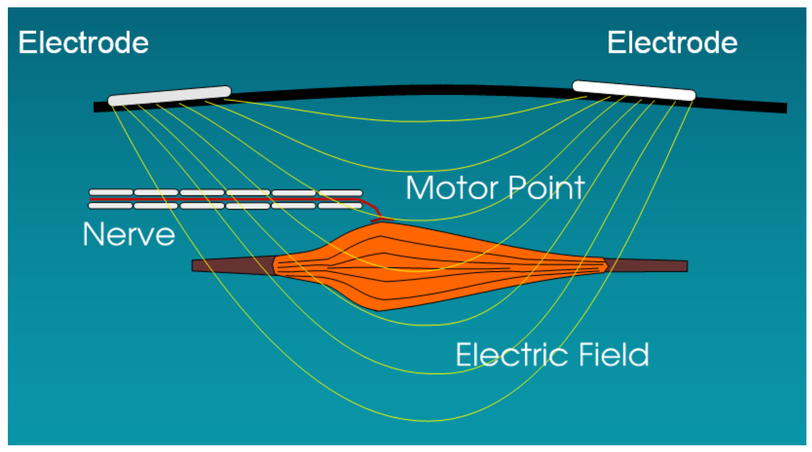
Need: Stroke is the highest cause of adult disability. Seventeen million strokes occur every year worldwide - one stroke every two seconds. Half of all stroke survivors lose the ability to perform everyday tasks using their upper limbs, which affects their independence. The UK societal cost is nine billion pounds per year.

Solution: Intensive movement practice can restore upper limb function lost following stroke. However, stroke patients often have little or no movement, so are unable to practise. Functional electrical stimulation (FES) activates muscles artificially to facilitate task practice and improve patients' movement.



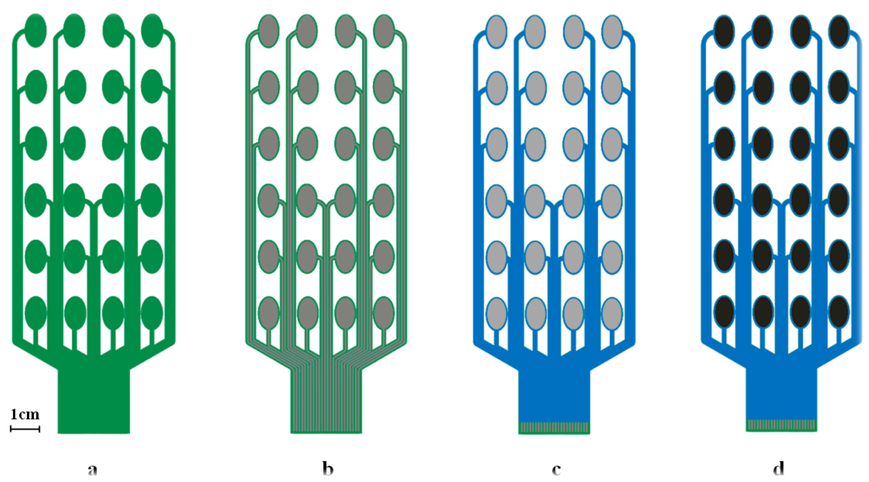
Electrical stimulation

Novelty: Current commercial FES devices use large electrodes which only stimulate a limited number of muscles, resulting in simple, imprecise, movements. Our work demonstrates the use of bespoke screen printable pastes to print electrode arrays directly on to everyday clothing fabrics. The resulting garments are integrated with cutting-edge sensor technologies and advanced control algorithms that adjust the stimuation based on past experience. Successful operation has been demonstrated by stimulating an optimised selection of electrodes in order to achieve different postures and assist performance of daily activities.

Competitive advantages: Comfortable to wear; Easy to use; Unobtrusive.

Fabrication and testing results

Fabrication process



Top views of the FES after the printing of each layer in sequence of: interface layer (a), conductive silver layer (b), encapsulation layer (c) and carbon loaded silicone rubber layer (d).

E-textile FES array sample

Material biocompatibility test

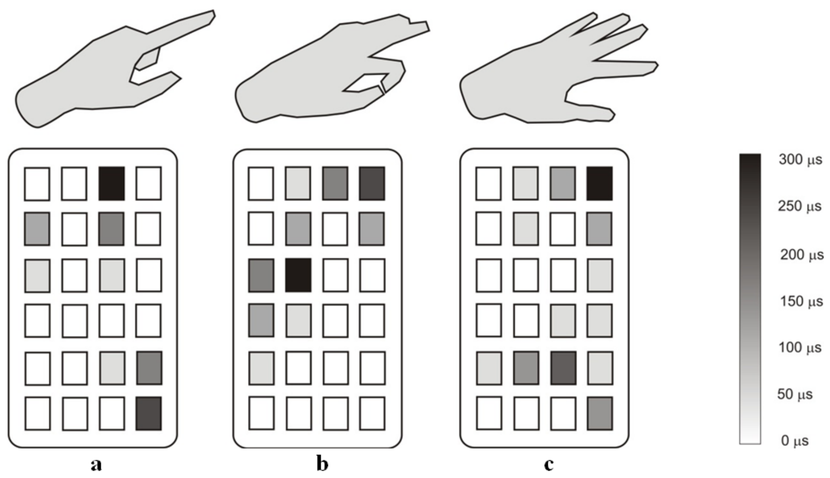
Material	Score	Result
Encapsulation	0	pass
Carbon/Rubber	1	pass

*Tested by Nelson Laboratories in US

ISO 10993-5: Agar overlay of L929 cells,

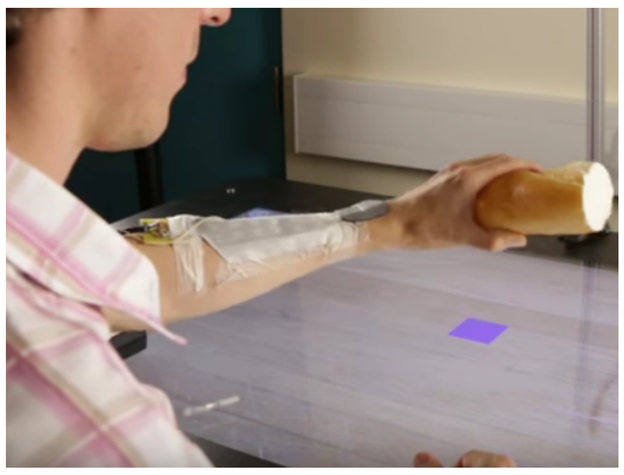
24 hours incubation.

Muscle stimulation results



Stimulation patterns for pointing (a), pinching (b) and open hand (c) gestures (shading indicates the pulsewidth levels).

E-textile assisting daily activities



Repositioning object

Closing drawer

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Summary

- The feasibility of manufacturing e-textile electrode arrays using printing technology has been demonstrated.
- The materials used have had biocompatibility confirmed using ISO 10993-5 cytotoxicity test results.
- Tests have shown that the electrode arrays can provide effective assistance of movement.
- Our MRC project will translate this technology from the feasibility stage to a functional prototype able to deliver a practical, comfortable, high performance solution for cost effective rehabilitation.