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Unified EEG-SEMG Platform for Accelerated Recovery of Motor Function after Stroke

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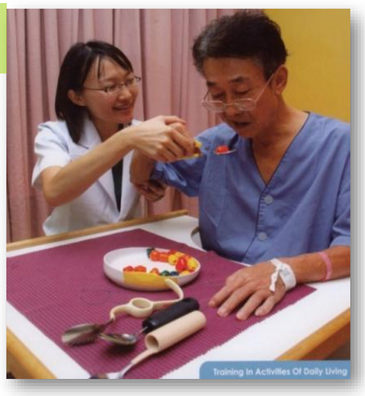
Introduction

The population of persons disabled after stroke has risen dramatically in the past decade, far outstripping the required number of therapists who can administer long term therapy[1]. The effectiveness of rehabilitation will be increased substantially if the patients are able to use a rehabilitation system at home, after having trained on it at the hospital[2]. Singapore faces 3 key challenges arising out of stroke:

1. Shortage of therapists
2. Shortage of bed space to provide adequate care
3. High rate of dropouts from therapy

By 2030, this problem would have escalated by about 300%[1,3,4]



Burning Problem

Only 6-10% recover fully

Stages of Stroke

Acute → Sub acute → Chronic

What is Currently Missing ?

- •Early Onset of Automated Therapy
- •Muscle and Brain Bio-feedback
- •Minimal Supervision, Guided Therapy

Aim

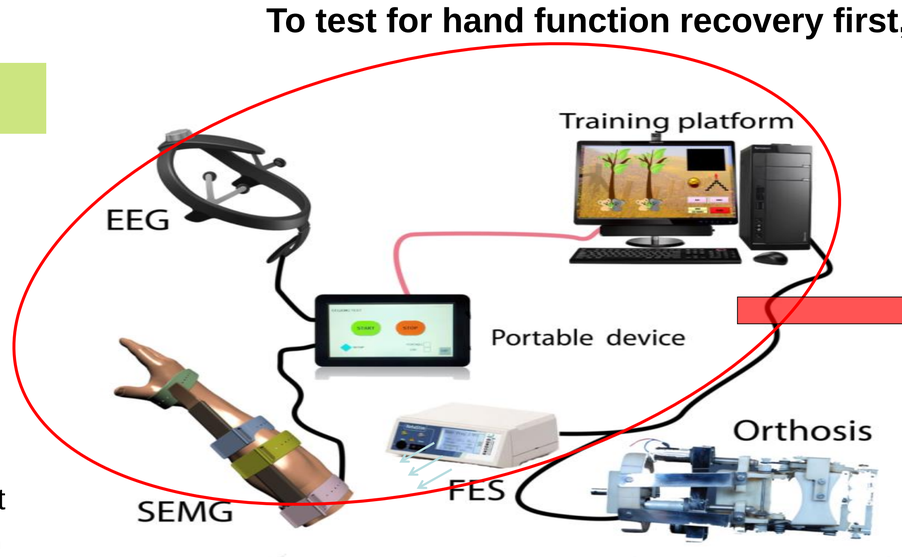
To design, build and test an integrated rehabilitation platform that can

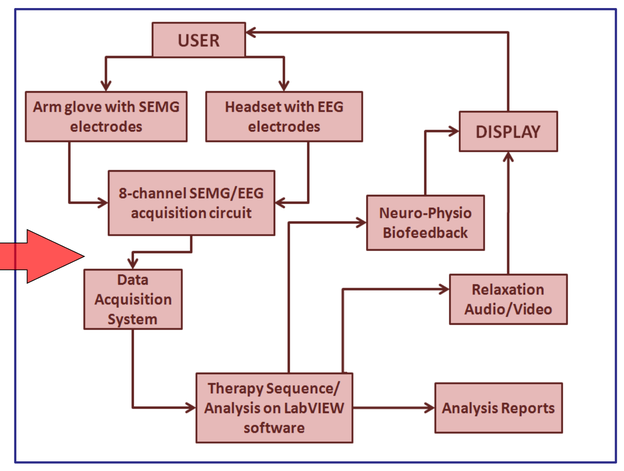
- give insight on progress of therapy at muscle and brain levels
- personalize therapy for accelerated recovery of function
- automate therapy intensity and difficulty levels
- run an orthosis or electrical stimulation device if necessary

To test for hand function recovery first, since it is key to independent living.

Methodology

1. A compact, wearable 16 channel data acquisition and storage device was built and tested for EEG and EMG
2. A dry electrode EMG arm glove and EEG headset was designed for usability with one hand
3. Subject was made to perform fixed tasks watching a mirror image video as well as muscle biofeedback (Fig 1)
4. A gaming interface built around agonist-antagonist biofeedback engaged the patient in therapy
5. A commercial FES system was integrated via a serial port interface to activate specific channels based on low EMG thresholds.

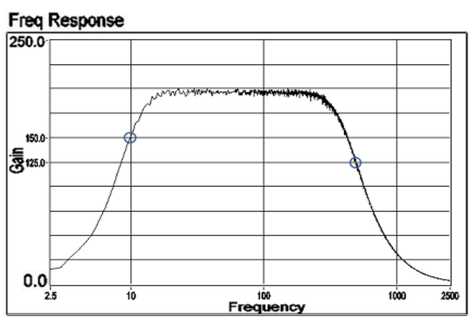




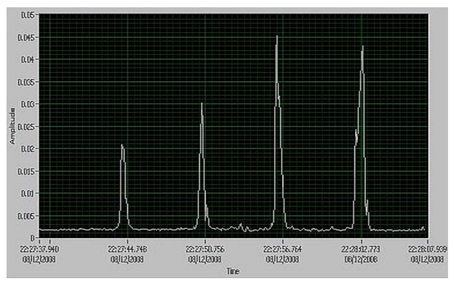
The Unified "SynPhNe" Platform (patent pending)

Results

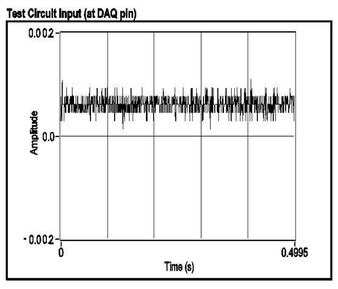
Signal Acquisition Testing



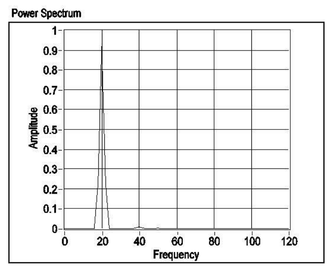
Frequency response of actual PCB in SEMG mode



SEMG (RMS) for 4 sets of left hand finger flexion



Noise affected output of 1/1000 voltage divider



Power spectrum of test Output in EEG Mode

The maximum signal amplification or gain values for DAQ circuit is about 20,000 for EEG signals and 200 for SEMG signals.

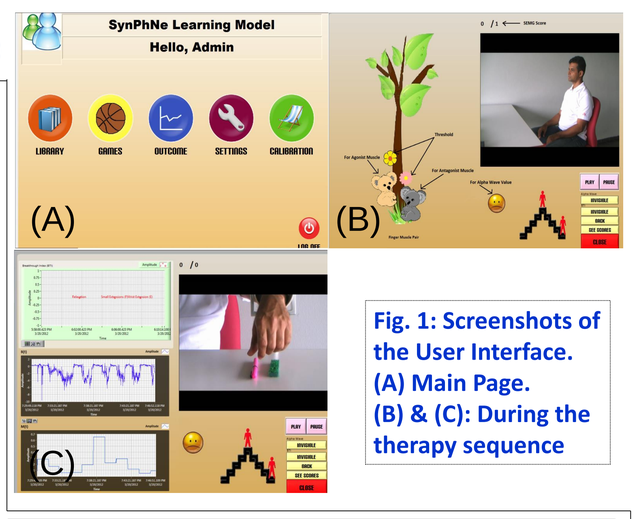


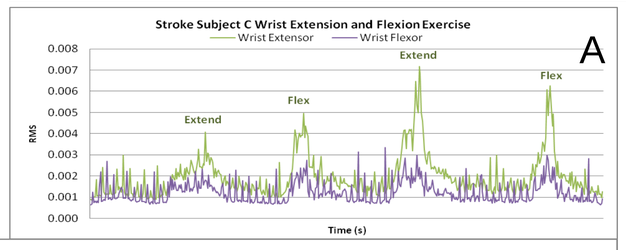
Fig. 1: Screenshots of the User Interface.
(A) Main Page.
(B) & (C): During the therapy sequence

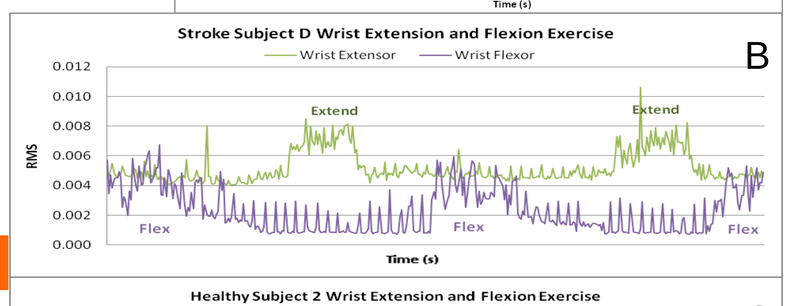
Healthy Subjects

Table 1. EEG changes-healthy subjects

Perfomance (based on ranking)	Subject No.	Mean difference (before and after therapy)	
		Relative Alpha	Relative Alpha / Delta-to Alpha Ratio
Good performers	1	0.0298	0.0131
	4		
Bad performers	3	0.1055	0.1184
	5		

1. Poor performance in SEMG measures, even for simple tasks, corresponded to larger changes in EEG parameters related to alpha and delta waves (Table 1), before and after therapy.
2. Inappropriate muscular co-contraction was seen even in some healthy subjects. This was quickly corrected using biofeedback (except in finger extensors which took much longer). A typical healthy SEMG profile for the wrist extensor and flexor is shown (Fig. 2 C).
3. FES was activated by achieving as low as 2% of maximum voluntary contraction for wrist and finger extensors and flexors.





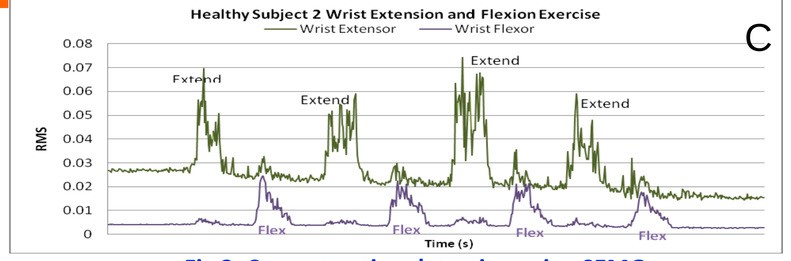


Fig 2. Co-contraction detection using SEMG

Stroke Subjects

1. Co-contraction detection was clear in severely impaired cases (Fig. 2 A) as well as in moderately impaired (Fig. 2 B).
2. Engagement and attention was enhanced by watching a video supported by bio-feedback. Those with Fugyl Meyer score > 18 responded best to EMG biofeedback, irrespective of age or days post-stroke.
3. Not all stroke subjects could achieve a lower EMG baseline on being instructed to relax their muscles.
4. In a pilot study, 7 out of 9 stroke patients responded by self-adjusting the SEMG agonist-antagonist peaks. Those with Fugyl Meyer score>18 may use the FES on need basis when tired, while those with lesser scores may use it for every repetition.

Conclusion

The platform detected differences in EEG/SEMG signals accurately, making it possible to track changes in brain state and muscle use. Larger changes in EEG parameters before and after therapy seemed to correlate with poorer performance levels in healthy subjects. It is worthwhile studying whether the same holds true for stroke patients. This could aid more accurate, real-time prognosis and therapy personalization. SynPhNe will enable a person to work with brain and muscle signals in a "mind-body" co-ordinated way. A patient will be able to alternate easily between active and passive therapy and also train in relaxation. This will help fatigue management. Further trials with stroke patients are currently underway in Singapore.

References: [1] N.Venkatasubramanian, CLH Chen, 2008. "Burden of stroke in Singapore", International Journal of Stroke, Vol 3 (Feb 2008) 51-54. [2] A.A. Timmermans,et al., Technology-assisted train-ing of arm-hand skills in stroke: Concepts on reacquisition of motor control and thera-pist guidelines for rehabilitation technology design. J Neuroeng Rehabil. 2009;6:1; [3] Population in Brief 2011 – A joint report by Ministry of Home Affairs, National Population and Talent Division of Prime Minister's Office, Sept 2011; [4] Asian Meta Centre Report for Sustainable Development Analysis, NUS, 1999

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