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AN AUTOMATED PHYSIO-NEURO RECOVERY TOOL FOR ENHANCING MUSCLE AND BRAIN CO-ORDINATION AND RECOVERY AFTER SPORTS RELATED TRAUMA AND INJURIES.

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Abstract

Injuries are common in high intensity sports such as rugby, martial arts, motor sports and the like. These sports result in not just limb injuries but also brain injuries affecting cognitive and motor function. One of the problems with long term neuro-muscular rehabilitation is that access to supervised therapy is difficult on a daily basis and family resources such as time and money can be severely strained.

SynPhNe is a wearable, portable, connected rehabilitation device which trains the brain and muscle as one system, rather than two distinct elements. It can highlight a person's unconscious muscle-brain reactions after injury and trauma which may be hampering recovery. These reactions are then self-corrected in real time using a dynamic relaxation protocol. The person trains to perform various exercises and tasks in an environment of dynamic activation-relaxation balance which helps not just muscle isolation but also outcomes based tasks.

SynPhNe was first tested among the stroke population. Stroke is considered a severe form of trauma affecting brain and muscle function. One outcome was that using SynPhNe requires substantially fewer repetitions to obtain results, as compared to conventional repetitive practice therapy. It was also possible for a non-medical person to use the device to administer guided therapy. Being automated with easy-to-build exercise options for different types of sports specific training schedules, it presents a promising option to help sports persons recover not just movement but also co-ordination and control in a safe, fast and low cost manner. This paper describes how the SynPhNe method could impact the sports injury and performance enhancement challenges of the future.

1. Introduction

The cornerstone of functional recovery after neuro-muscular trauma has been repetitive practice therapy [1]. Some even recommend high intensity or robotic therapy [2],[3],[4]. The underlying rationale for this is that with many repetitions over time, the damaged brain will rewire itself and build new neural pathways to effect motor activity in the limbs [5]. This approach has met with some success in clinical studies [6] but uptake and adherence to high intensity repetitive practice has been low. Patients suffering brain injuries in sport require far more extensive therapy if they wish to go back to their sport after recovery. This means many more therapy hours which, at some point, need to be sport specific and have a significant motor-function component. The therapy is skilled manpower intensive and involves both patient and care giver travelling to specialized clinics and being dependent on the timely and regular availability of therapists, who are often in short supply.

1.1. SynPhNe Rehabilitation Device: This paper briefly describes the principles behind SynPhNe, a synergistic physio-neuro rehabilitation tool which trains the brain and muscle as one unit. It captures brain and muscle signals and enables people to self-correct movements in real-time after trauma or injury. A technology like SynPhNe (Fig 1) can assist a patient to maintain regular therapy at home in the early stages of recovery, ensures low fatigue and provides guided task and sport specific training using an audio-video interface. The changes in the ability to work the muscle and brain are captured in quantitative terms for the specialist or therapist to assess progress and customize therapy. Being very light, wearable and connected, it allows easy accessibility and affordability. In this paper, we draw lessons from results obtained with stroke patients and extend the principles of the finding to show potential application for sports persons who have suffered brain-muscle injuries.

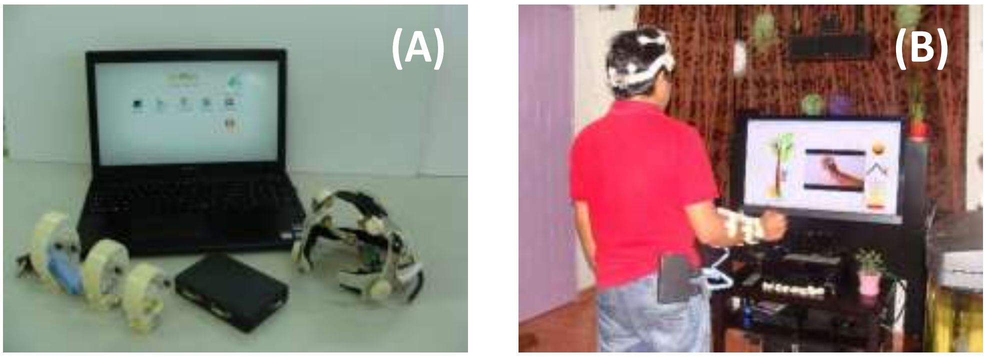

Figure 1. The SynPhNe device as hospital/clinic (A) and home (B) versions.

2. Experimental Work

An initial pilot study with severe, moderate and mildly affected stroke subjects showed that most subjects could effect self-correction of unconscious muscle activity given the correct feedback in real-time. This led to immediate, although short-lived gains in performing actions and tasks [7]. The subsequent experiments with stroke subjects was designed as a thrice a week intervention for four weeks, with each session consisting of below elbow muscle isolation (20 min) and task performance practice (20 min). Each exercise was repeated just 5-10 times and done at a slow pace which ensured enough time for self-correction of compensatory habits and self-inhibition of maladaptive, unwanted muscle activity. All exercises were performed at a table sitting down. The audio-video interface on a computer screen demonstrated the actions and tasks which the subjects imitated in real-time. EMG signals were captured from the muscles and EEG signals from the brain using a specially designed wearable circuit [8]. These signals were processed and used as simultaneous feedforward and feedback on the same screen as the video to facilitate the dynamic self-correction, while the software calculated muscle activation and relaxation thresholds and appropriate difficulty levels for the patient using these thresholds. The study design was not very specifically for stroke only but similar to other studies in the fields of hemiplegic cerebral palsy and traumatic brain injury, which face similar rehabilitation challenges [9], [10].

In all, 24 subjects were tested at two different centres in Singapore. Clinical assessments were done at Week 0, Week 2 and Week 4 to test outcomes. All subjects gave informed signed consent and the ethics approval was provided by the institutional review board of National Healthcare Group, Singapore.

3. Results and Discussion

Conventional as well as robot assisted therapy focus on repetitive muscle activation when training motor tasks. However, results from EMG signals in our study showed that the ability to do repetitive contraction movements volitionally with a muscle is well associated with ability to relax the muscle below a threshold close to its resting state immediately after (Fig 2). This association (P=0.000, R-sq=0.61) was present for all subjects, independent of affected dominant or non-dominant arm and severity.

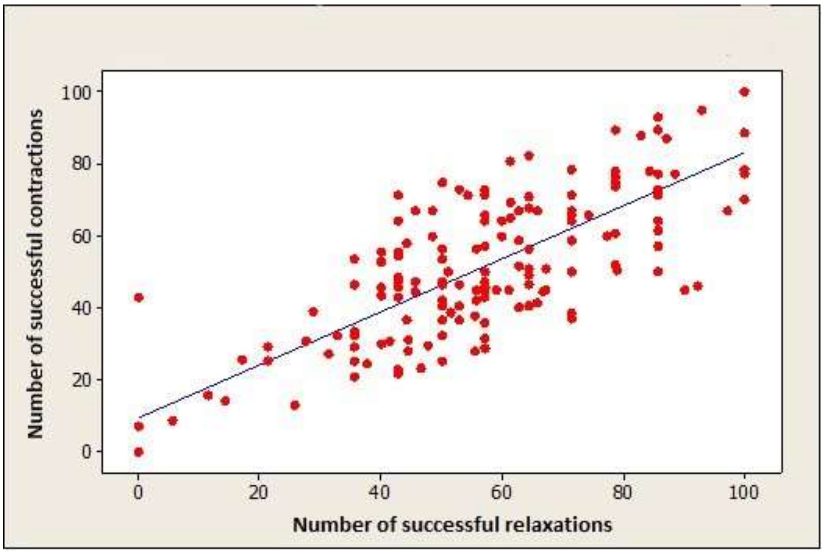

Figure 2. Association of muscle contraction and relaxation.

Not only did most subjects improve their ability to manage agonist-antagonist balance in real-time while performing various muscle isolation actions, but these also translated into better performance in ADL tasks practiced immediately after. The EEG metrics helped to trace whether the appropriate hemisphere was being activated and whether there was any improvement in inter-hemispheric inhibition which was reduced after trauma. Subjects showed a significant improvement as per standard clinical scale of function such as Action Arm Research Test (ARAT) and Box and Block test. Mean percentage improvement in clinical scale score with respect to starting baseline (after normalizing to full score and discarding maximum and minimum values as outliers) for ARAT was 20.12%(SD=19.54%) and for Box and Block Test, 23.81%(SD=28.65%). 79% of subjects showed positive changes in ARAT while 60% of subjects showed positive changes in Box and Block Test.

The principle of training muscle activation and relaxation simultaneously was successfully used to rehabilitate even those whose recovery has plateaued many months after trauma, in this case, stroke. Such a method may also be tried for those sports injuries where the patient finds it difficult to regain motor function and co-ordination after suffering neuro-muscular trauma, which is common in contact and high speed sports. The SynPhNe device can be used at bedside or at home, thus reducing the number of supervised hours necessary from a therapist. It was found enjoyable and safe to use as shown in the self-rated scores administered to the users in the above experiment (Fig 3) across all subjects, irrespective of extent of recovery after using SynPhNe.

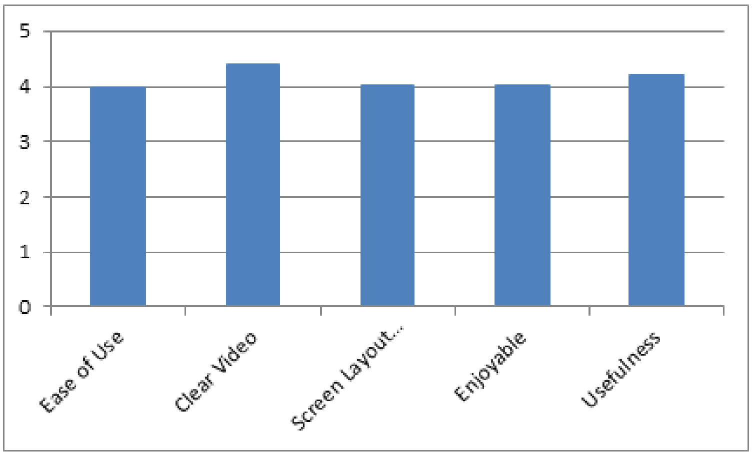

Figure 3. User rated scores on a scale of 0-4 across all subjects

4. Conclusions

Although high intensity repetitive practice is the current norm in both conventional and robotic therapy, experiments using the SynPhNe method suggest that significant recovery is possible if brain and muscle signals are used as visual feedback for patients to self-correct both activation and inhibition in real time. In this way, real-world task specific practice can help train brain and muscle together in a tightly coupled manner with much fewer repetitions and significantly less fatigue. The wearable SynPhNe device holds the promise of filling a key technology gap for functional recovery of motor function for a wide variety of mild to severe sports injuries and trauma, and to enhance performance in those who may have made unconscious adaptations after injury or pain.

Acknowledgement

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