Equilivest: A Robotic Vest to aid in Post-Stroke Human Balance Rehabilitation

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***Abstract*—Stroke is a devastanting disease that affects bla bla bla. It has been shown that neurofeedback can help patients to regain lost motor activity and recover functionality. In this work, we are proposing a device that help patients by augmentation sensory sensation and pinning information to certain patterns in gait. We are presenting results from surveys to patient's caregivers, patients and medical personal. We are presenting the experimentation paradigm, and the robotic device that we created to help the patient.**

***Index Terms*—component, formatting, style, styling, insert**

I. Introduction

Brain stroke is a devastating disease. It affects worldwide population and is the main cause of disabilities worldwide. Disabilities related to stroke can affect motor pathways, and may lead to several motor disability disorders. Hence, as early as possible the rehabilitation can be put into place, better the outcome that can be obtained by the treatment.

Strong evidence suggests that neuroplasticity can be enhanced by neural rehabilitation [1]. These procedures are aimed to relearn movements that can trigger new pathway generation which reroute, or even completely replace, those pathways that were damaged by the stroke. Neurorehabilitation procedures are performed by a group of interdisciplinary care givers and technicians. Recently, biofeedback techniques, aiming at providing extra information to the patient that can be used to aid in the relearning has appear as an alternative treatment to increase neuralplasticitly, in the form of Wearable devices-based biofeedback rehabilitation (WDBR) home rehabilitation, or even daily use [2]. Authors found evidence that biofeedback can indeed help rehabilitation procedures.

This work relies on the following idea: the addition of an independent and new signal, that can be assimilated as an extrasensory input, could provides extra information which could improve dynamic balance performance on stroke patients which may have yet insufficiency to deal properly with walking. The idea is that we have now the ability to provide meaningful balance information with hardware and software that can provide this extra signal in the form of any form of stimulation, for instance vibrotactile.

We are presenting here the development of a device which is grounded on this idea, and is aiming to help a post-stroke patient with a dynamic balance problem as a case study. This is implemented with a smart-vest [3], which we will call, equilivest, that can detect some particular situation and implement in a way to fix one particular problem. We aim to provide motor learning, which means that you need to provide a fading vibrotactile feedback, and that the signal needs to be provided in a way which is less conscious as possible. The device is based on the idea to promote plasticity by giving her vibrotactile stimulation based on kinematic and dynamics measurements. The idea is to exploits these ideas from neurofeedback that we can create ”external” sensors by providing some form of vibrotactile stimulation on her belly and link that stimulation to some form of measurements from IMUs (inertial sensors).

The form of validation procedures that is required in clinical settings [4].

Section presents the case study. Next section presents the underlying clinical hypothesis that this work is trying to promote. Finally section this and that present the experimental design. Results are presented on the next section, and this work concludes with discussion and conclussion.

II. Materials and Methods

A. Single Patient Case Study

Patient is a 31 years old female, perfectly healthy, who suffered an acute brainstem stroke after giving birth The stroke was on posterior fossa subarachnoid due to a brain artereovenous malformation (AVM), which was somehow facilitated by pregnancy or puerperium [5]. Patient was in

Identify applicable funding agency here. If none, delete this.

coma for around 2 months, after that unable to walk, move, talk or swallow. After two years of intensive rehabilitation, Patient managed to recover significantly, including from dysphagia, which were very important in order to remove the feeding tube allowing her to start speech recovering.

After 24 months since event, the patient, was discharged from hospital and only maintained a 3 times per week rehabilitation treatment, focusing on a remaining affection related with dynamic walking balance problems. Patient achieved higher index scores in static balance tests and is fully able to hip-balance and ankle-balance. Patient has recovered muscle in her legs and can perform lower-limb workouts without problems. Her vision is normal. Somatosensorial system is optimal on foot sole. Tests performed to verify proprioceptive system were successfully passed.

However, when Patient tries to walk on open-spaces, or with confronting lights (like walking towards sunlight) or with other people moving around, she is unable to keep up with the pace of the gait and falls frequently. This is consistent, under these three situations. Nowadays, the patient can walk with a Canadian cane or a non-actuated walking helper which she is hesitant to use, both.

B. *Underlying hypothesis*

Human balance is composed of a complex interaction of different subsystems, which includes somatosensorial information, vestibular system, visual information, which is later processed in different networks of the Central Nervous System, and actuated by motor pathways at many different scales.

Tables **??** and **??** show the results of the surveys performed on the Patient and their main Rehabilitaion caregivers. Using the results from the surveys, we postulate three different systems that could benefit from the introduction of an external signal in the form of biofeedback that can aid in rehabilitation procedures.

- Vestibular information on fusion of vestibular information
- Bradykinesia: the processing speed required to effectively perform the processing and actuation is not enough.
- Unusual gait

Based on the surveys and the information provided by caregivers there seems not to be any somatosensorial deficit [**?**].

C. *Robotic Device Vest*

Description of the system. How does it work, how is the detection of IMU working Internet of Robotic Things. Arduino

Why only vibrotactile stimulation and not auditory stimulation

D. *Experimental Design*

Three experiments were designed in order to test each one of the hypothesis. All the experiments were approved by the ITBA University ethical committee. Participants were recruited voluntarily.

1) Vestibular Feedback: The underlying idea is that signals from IMU can be feed back to the patient by vibrotactile stimulation on their belly. The hypothesis is that if there is a vestibular problem that forbids the patient to receive or evaluate the vestibular information appropriately, this external signal can be available for the patient to integrate it into the dynamic balance integration.

In order to test it, 5 healthy participants are going to be recruited to simulate falling breakpoint conditions on the IMU information. Participants wear the vest and perform a forward walking exercise with the upper-trunk leaned forward at different angles progresively until they can no longer cope with the unbalance situation without stepping forward.

Afterward, the experiment will be repeated with the 5 participants activating the vibrotactile stimulation which will map progressively the inclination angle. Hence it will provide an extra signal that can give a accurate information in relation to the stability of the upper-trunk in relation to the walking gait.

2) Bradykinesia: Fall prediction due to insufficient speed of step: All the IMU information represent a multichannel time series. Hence, it can be used to predict a falling situation.

In this case, 5 healthy participants perform 20 controlled falls over gym mats.

(3) Ver en base a la encuesta como se da la situación de caída más común que Paula relata, en base a lo que ella manifiesta. Entonces lo que hacemos es tomamos 5 sujetos y los hacemos caer 5 veces cada uno sobre la colchoneta (o 10 o 20 x sujeto, lo que más puedas). Con estos datos, que son series de tiempo de 6 variables, intetamos ver si con un modelo de ML podemos predecir el momento de la caída simulada de cada uno de ellos y ANTICIPARNOS . La idea entonces es que suene el motor cuando el sistema detecta con antelación que puede venir una caída inminente. Aca se muestra el accuracy en la detección de la caída en los datos recabados.

10 participants simulating falls.

3) Gait Pacemaker: This is a gait pacemaker coupled with a podometer. It has been showed that gait synchronization with music achieved better effect [6].

(4) En este caso, lo que hacemos es armar un gráfico de gait y lo que hace el dispositivo es detectar un punto en el ciclo y vibrar de forma recurrente, como un marca paso, basado en un podómetro. En este caso, tomás 5 personas las hacés caminar, determinás cómo son esas curvas y accionás el motor siempre en el mismo momento. Lo que mostramos son los gráficos y el momento donde se dispara la estimulación.

RESULTS

(1) Se muestran entonces esos dos gráficos promediados de cada uno de los 5 sujetos (10 series, 5 sin el motor, 5 con el motor).

(2) Se muestra los gráficos de las series de tiempo offline de los datos analizados y como el sistema online de predicción acierta justamente en anticipar la caída. (Esto es probablmente desde software lo más complejo).

(3) Este caso probablemente sea el que requiera más experimentación sobre Paula en sí misma. La idea acá es tener los gráficos promediados de GAIT, que son todos cíclicos, de dos de las variables cualquiera del IMU que formen un ciclo, y ver que hay un patrón común que se da más o menos para las personas healthy. En base a eso, luego la idea es probar si con Paula ese patrón CAMBIA. A partir de que vemos si cambia hay que ver donde cambia y en ese punto meter el pacemaker.

Discussion

Conclusion

This device used as a testbed can be extended easily to provide biofeedback which also aim to increase the effectiveness of rehabilitation procedures [7].

Acknowledgment

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