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

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***Abstract*—This document is a model and instructions for LaTeX. This and the IEEEtran.cls file define the components of your paper [title, text, heads, etc.]. *CRITICAL: Do Not Use Symbols, Special Characters, Footnotes, or Math in Paper Title or Abstract.**

***Index Terms*—Stroke, Balance, Rehabilitation, Biofeedback, Vibrotactile**

I. Introduction

Brain stroke is a devastating disease, that affects world population and is the main cause of disabilities worldwide [1]. Disabilities related to stroke can affect motor pathways, and may lead to several motor function disorders. One important aspect of motor function is balance which is the ability to control the center of mass of the body inside the base support provided by the lower limb. Stroke can affect dynamic balance as well, which is manifested while walking and that affect autonomy, independence and is an important factor in activities of daily living (ADL) particularly for young patients [2], [3].

Strong evidence suggests that neuroplasticity can be enhanced by neural rehabilitation [4], [5]. 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 caregivers and technicians. Recently, biofeedback techniques, aiming at providing extra information to the patient that can be used to aid in the relearning have appeared as an alternative treatment to increase neuralplasticitly. These are in the form of Wearable devices-based biofeedback rehabilitation (WDBR) [6] or more advanced robotic rehabilitation gait devices [7]–[9].

The working hypothesis is as follows: the addition of an independent and new peripheral therapeutic signal, that can be assimilated as an extrasensory input, could improve dynamic balance performance on stroke patients which may have yet insufficiency to deal properly with the complexities of 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, particularly vibrotactile feedback (VF). Although the effectiveness of biofeedback on static balance has been tackled extensively in the literature, works dealing with dynamic balancing problems have been negligible.

This work presents the development of a device which is grounded on this idea, and aims to help a post-stroke patient with a remaining dynamic balance problem, and present it as a case study. The proposed development is implemented as a smart-vest [10], which we will call, equilivest, that address three possible clinical hypothesis of the underlying problem. We aim to provide motor learning, meaning to provide a fading vibrotactile feedback signal which is as less conscious as possible [3]. The device aims to promote plasticity by providing timing vibrotactile stimulation based on kinematic and dynamics measurements.

Section presents the case study. Next section summarize the results of the interviews and surveys performed by the patient, their family and professional caregivers. Based on the analyze of the data, the next section presents the underlying clinical hypothesis. Section A describes the vest details and architecture. The experimental design protocol is expounded in Section B. Preliminary results are presented on the next section, and this work concludes with discussion and conclusion.

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 likely affected

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

by pregnancy or puerperium [11]. Patient was in coma for around 2 months, and 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. The patient achieved satisfactory index scores in static balance tests and is fully able to perform hip-balance and ankle-balance. She has recovered muscle in her legs and can perform lower-limb exercises. Her vision is normal. Tests performed to verify proprioceptive system were successfully passed.

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

Based on the surveys and the information provided by caregivers there seems not to be any somatosensorial deficit [3]. There isn't any report of somatosensorial on foot sole.

B. Underlying hypothesis

Human balance is composed of a complex interaction of different subsystems, which includes somatosensorial information, vestibular system and visual information as input sources. These are later processed in different networks of the Central Nervous System, and finally actuated by motor pathways at many different scales [3].

We perform a series of surveys and interviews with the patient and their caregivers. Main results are summarized in Tables **??** and **??**. Based on the clinical history, the results from the surveys and interviews, we postulate three different potential clinical situations that could use the external signal in the form of biofeedback and could potentially aid in rehabilitation procedures.

- Vestibular information or fusion of vestibular information
- Bradykinesia: the processing speed required to effectively perform the processing and actuation is not enough.
- Unusual gait: due to ataxic gait the movement is not normally regulated.

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) Gait Pacemaker: This is a gait pacemaker coupled with a podometer. It has been showed that gait synchronization with music achieved better effect [12] and there are effect on gait trainer on patient [13]. During this experiment 5 participants walked 5 meters distance. IMU information was obtained to derive standard diagrams of gait patterns. They were compared against those obtained for the patient under study. And it was determiend the exact moment when the deviation against the patient was greater and the VF was triggered upon that.

E. Participants

Participants are recruited voluntarily and the experiment is conducted anonymously in accordance with the declaration of Helsinki published by the World Health Organization. No monetary compensation is handed out and all participants agree and sign a written informed consent approved by the ITBA University Research Commission.

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,

Question
Podes describir cómo y cuándo se expresa la perdida del equilibrio y su proceso? - Esta pregunta nos servirá para determinar co
¿Siempre se desarrolla de la misma manera? - Con esta pregunta queremos profundizar sobre la anterior
¿Cuál? Si la respuesta fue no, deje sin contestar
¿Podés evidenciar cuando estas por empezar a perder el equilibrio? - Con esta pregunta intentamos conocer un fe
Si la respuesta fue si ¿Qué sentís?
¿Con qué frecuencia usas el andador? - Puede seleccionar mas de una opción. Así nos ayuda
¿Existe algún denominador común en las caídas? - La presencia de este sería importantísima para un fenómeno o señal a medir y caracterizar que sería muy útil para la
¿Cuál? Si la respuesta fue "No" deje la respuesta en blanco
¿Cómo estás trabajando la recuperación hoy por hoy? - Con esta pregunta buscamos conocer el e
¿Hay algo más que desees comentar o expresar?

TABLE I
TABLE

Answers to survey questions.

Question
¿Cuál es la razón de la pérdida del equilibrio en la paciente? - Esta pregunta nos permite conocer
¿Podes describir cómo y cuándo se expresa la perdida del equilibrio y su proceso? - Con la descripción podemos comprender com
¿ La paciente puede caminar sin un dispositivo de tipo ayuda marcha? De ser así, ¿Bajo que circunstancias? - Conociendo mejor la situ
¿Presenta una pérdida de fuerza muscular que dificulte el caminar? - Esta pregunta permite conocer el caso en mayor
¿Presenta dismetría? - Nuevamente queremos adelantarnos a hipótesis erróneas a la hora de decidir el método de sensado y procesamiento de las señales. La
¿Presenta temblores? - En caso de presentar temblores estos se verán reflejados en las señales y es
¿Presenta alteraciones en la marcha en instantes previos a la caída? - En caso de existir algún impulso inicial que podamos sensar
¿Cuáles? Si la respuesta fue "No" deje en bl
¿Sufrió alteraciones en la sensibilidad profunda? - Existe un trabajo previo en la Universidad de Buenos Aires que usa un método de sensado c
Antes de perder el equilibrio, ¿Trastabilla?¿Acelera la marcha? - Al igual que en otras preguntas buscamos obtener información extra para el procesamiento de las señale
Si la respuesta fue 'Otro síntoma' ¿Cuál? - En caso contrari
¿Presenta algún tipo de marcha patológica? -la caracterización del caso permite decidir
¿Cuál? Si la respuesta fue "No" deje la respuesta
¿Existe algún denominador común en las caídas? - La presencia de este sería importantisima para un fenómeno o señal a medir y caracterizar que sería muy
¿Cuál? Si la respuesta fue "No" deje la respuesta
¿Se hizo un estudio de evaluación de marcha? - Esta pregunta podría aportar información suplementaria a preg
¿Se hizo evaluación de riesgo de caídas? - Esta pregunta puede aportar algo de info
¿Hay alguna manera en que trabaje en la reeducación de la paciente? - Quisiéramos conocer un poco mas la situa
¿Hay algo mas que desee comentar o expre

TABLE II
TABLE

Answers to survey questions.

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 [14].

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