Clinical Impact of Innovative Neuroprothesis on Activities of Daily Living (ADL): First Set of Users Evaluations*

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Abstract. MUNDUS is an assistive framework for recovering direct interaction capability of severely motor impaired people based on arm reaching and hand functions that exploits any residual control of the end-user. The MUNDUS controller integrates information collected by electromyography, head/eye tracking, and brain computer interface commands. MUNDUS actuators modularly combine a lightweight and non-cumbersome exoskeleton for arm weight compensation, closed-loop controlled Neuro Muscular Electrical Stimulation for arm, hand motion and grasping of collaborative functional objects recognized by radio frequency identification. MUNDUS prototype has be tested by a first group of end-users (N=6) in different configurations depending on the users clinical conditions in order to test all the modules. Even if the end users tested until now didn't perform the complete testing protocol, all end-users were happy of using the system and very willing to re-perform tests. They assessed a positive feedback on the system functioning.

1 Introduction

Restoring and augmenting human capabilities compensating for reduced motor functions and disabilities may be carried out by different approaches, all of them finalized to restore some missing functions or capabilities in involved people [1]. The International Classification of Functioning, Disability and Health (ICF)[2] well copes with subjectivity in the identification of the functions able to assure human dignity and self-esteem. People, coming from a personal history of severe traumas or neuromuscular diseases that have led to a sudden or progressive loss of motor capabilities, attribute a high value to the maintaining of direct interaction with the objects of the daily life [3]. Simple gestures, such as taking autonomously a glass, bringing it to the mouth and drinking, are actions that contribute to a positive assessment of own quality of life. The most of assistive technologies solutions for people with severe motor impairments hardly surrogate the natural human interaction with the objects of the daily life. The interaction with the environment is generally mediated by different interface devices and basic upper limb motor

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functions (i.e. grasp an object) are implemented by robotic arms such as manipulators. Robotic arms did not get a wide success in the past because of their cumbersomeness, high costs and reduced acceptability by the users. An innovative solution may be offered by customizable and modular systems able to exploit any residual motor capability allowing the natural motion of the arm in the space.

MUNDUS is an assistive framework for recovering interaction capability of severely motor impaired people based on arm reaching and hand function. Sensors, actuators and control solutions adapt to the level of severity or progression of the disease allowing interaction through the voluntary control by the user.

The aim of this paper is to describe the preliminary results about the use of MUNDUS system on end users.

2 Material and Methods

2.1 Subjects

MUNDUS end users are people affected by neurodegenerative disease such as Amyotrophic Lateral Sclerosis (ALS), Friedreich Ataxia (FRDA), Multiple Sclerosis (MS) and high level of Spinal Cord Injury (SCI).

The subjects recruited for these preliminary tests have been selected in order to fix the setup of the whole system, testing different configurations of the system according with patients' needs and characteristics. In Table 1 there is the description of first set of end users recruited.

Table 1 Recruited Subjects

Patient	Age	Gender	Pathology
FS001	44	Male	SCI level C3-C4
RF002	37	Female	MS
ND003	79	Male	SCI level C4-C5
EL004	18	Female	SCI level C4
AG005	74	Male	ALS
GD006	45	Male	MS

All subjects recruited signed informed consent form according with project Ethical Guidelines.

2.2 MUNDUS System Setup

Before the execution of each trial, exoskeleton (EXO) was adapted to patient size, the workspace was checked to be sure that all points could be reached by the subject without limitation or discomfort and then all sensors were calibrated. The experiments performed can be divided into five protocols, as described in Table 2.

Table 2 Protocols

Protocol	Description	Aim
1	Only EXO	Evaluate effect of arm weight support
2	EXO plus EMG	Evaluate effect of arm weight support on muscle activation
3	Only HAND without or with EXO	Evaluate the effect of NMES on the grasp/release of the target object and identify the best configuration of stimulation setting
4	Only ARM NMES plus EXO	Evaluate the effect of NEMS on the arm space exploration in order to reach target position and identify the best configuration of stimulation setting
5	EXO plus ARM NMES driven by EMG recording and HAND	Evaluate the effect of NMES modulated by EMG signal on the shoulder and elbow muscles and EXO support to perform target movements. The configuration included also the hand stimulation.

For each trial, video, angles and data from EXO sensors, Surface Electromyography (EMG) data and Neuro-Muscular Electrical Stimulation (NEMS) profiles were recorded.

3 Results

In this section data of subject GD006, who performed protocol 5, are reported as example.

Movement required to GD006, presented in Fig. 1, was drinking task supported by the EXO, the EMG-NMES arm module and the hand NMES module. Movement is divided into its sub-phases; in particular form left to right: initial position, target reaching, open hand, target grasping, hand to mouth, target retuning, open hand, final position are presented in Fig.1.

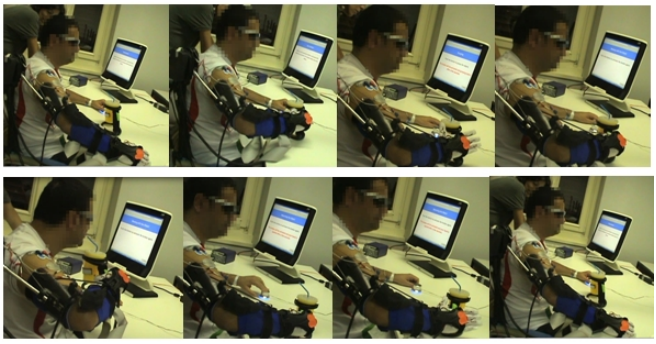

Fig. 1 GD006 movement sub-phases

To perform the task, two muscles were stimulated according to the residual muscular activity: the biceps and the medial deltoid. The stimulation intensity respectively was fixed at 20 mA and 40 mA, while the pulse width was modulated between 0 and 450 μs according to the residual EMG activity detected by the adaptive filter. Fig. 2 shows the results obtained by GD006 while performing the required task.

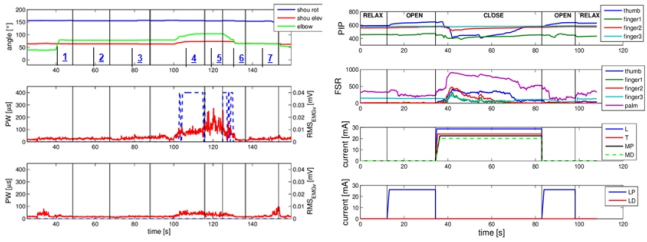

Fig. 2 Results obtained by GD006 during drinking task

In the left upper panel the angles of the exoskeleton are shown, whereas in the middle and in the lower left panels the pulse width (dashed blue line) and the Root Mean Square (RMS) of the voluntary EMG (red solid line) are shown. All the sub-actions were triggered directly by the user by means of an USB-button controlled by his left hand, as shown by the vertical lines in the Fig. 2. The first line indicates the instant in which the user reached the cup and activated the brakes to hold the position. The second trigger indicates the instant in which the user wanted to open the hand; then, the user got closer to the object and triggered the grasping of the cup. When the object was grasped, the brakes were automatically deactivated and the user was free to reach the mouth. Once there, he triggered the activation of the brakes. Afterwards, he deactivated the brakes to go back to the table and when the table was reached he sent another trigger to open the hand and finally to relax the hand.

In the first right panel from the top of Fig. 2 the kinematics data acquired by the instrumented glove at the proximal interphalangeal joints are reported; in the second one, the force data measured at the finger tips are shown; in the third, the stimulation intensities provided to the matrixes that induce the closing of the hand are reported; finally, in the last panel the stimulation intensities provided to the matrixes that induce the opening of the hand are depicted.

4 Discussion

These preliminary tests have mainly focused in the assess of the functionality of the integrated platform, adapting it to end users. The main observation is related to the different setup required between healthy subjects and end users. In fact all the preliminary tests on healthy subjects shown that the system was ready to be used

on end users; on the contrary some adjustments were necessary to adapt the system to subjects with different clinical characteristics. For example the EXO was adjusted to assure to the subject the best space exploration favoring their functional joint restrictions. The arm weight compensation needs to be well calibrated to avoid that an extra compensation could limited the return on the rest position at the end of the task. On NEMS side the choice of a matrix of electrodes that can allow a fine selection of target muscle has proved to be very good. In fact in this way it was possible to control the grasp and release of the hand with a valid grasp force necessary to perform the drinking task.

5 Conclusion

Even if the real end users tested didn't perform the complete testing protocol, all end-users were happy of using the system and very willing to re-perform tests. They assessed a positive feedback both on the using of the exoskeleton and of the NMES.

References

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