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Robot-assisted rehabilitation treatment of a 65-year old woman with alien hand syndrome

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Abstract— **Allien hand syndrome (AHS) is a rare neurological disorder characterised by uncontrollable and involuntary movement of upper limb. In Fact, the patient feels it as extraneous part of his/her body. From our knowledge, this paper reports the first results of using robot assisted therapy for rehabilitation of patients with AHS syndrome. It is noticeable that the improvements in the capability of carrying out activities of daily living and in the control of the hand and arm are impressive despite of the progress of her neurodegenerative disease.**

I. INTRODUCTION

Alien hand syndrome (AHS) is a rare neurological disorder in which arm and hand movements are performed without awareness or conscious will [1]. There is a strong role of rehabilitation for the treatment of this disorder. As it was reported by [2], over the course of 4 months the rehabilitation treatment targeted toward the specific needs of the patient, allowed improvement in his activities of daily living (ADL). In the same sense, the work, reported by [3], concluded that inpatient rehabilitation improved hand control and capability to use the hand in a functional manner. There are more cases reported in the scientific literature about the use of rehabilitation treatments to improve the recovery of these patients.

On the other hand, many robotic devices to deliver rehabilitation therapies for upper-limb recovery has been developed in the past [4], [5], [6], [7]. Recently, a scientific statement published by the American Heart Association in the Comprehensive Overview of Nursing and Interdisciplinary Rehabilitation Care of the Stroke Patient and a recomendation published by the Department of Veterans Affairs and Department of Defense in the Clinical practice guideline for the Management of Stroke Rehabilitation says that ”Robot-assisted movement therapy can be used as an adjunct to conventional therapy in patients with deficits in arm function to improve motor skill at the joints trained” [8], [9].

The first results of using a robotic device to deliver rehabilitation therapy to a 65-year-old woman with alien hand syndrome are presented in this paper. Our hypothesis is that the intensive robot assisted therapy could be beneficial for the recovery of patients who suffer rare neurological disorders, such as AHS. Our findings are that the patient has improved her hand and arm control and therefore, the capability to carry out ADL without assistance.

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II. MATERIALS AND METHODS

A. Subject

A 65-year-old woman, right-handed professional pianist complained of slowly progressive clumsiness of her dominant arm over 5 years. She was well until the age of 60, when she first noticed impairment of the controlled movement of her right hand when playing the piano. She felt as if her arm ”did not do what it was supposed to” and refused to play because it was ”too clumsy to practice”. Occasionally, when performing movements with his left hand, right hand moved upward unintentionally. She had a felt of strangeness and astonishment with the behaviour of her abnormal hand and referred about it as if ”it had an entity of its own”. After two years, she had serious problems to play and, though her right hand was not paretic, her movement was markedly delayed. The hand continued its foreign and uncooperative behaviour, which completely prevented her from playing. Its main features on clinical examination were prominent right constructional and bimanual apraxia and feelings of estrangement of the limb coupled with non-purposeful movements such as levitation, especially when attention decreased, all consistent with posterior alien hand syndrome (AHS). She did not show, however exploratory behaviour, groping or compulsive manipulation of objects reported in anterior AHS. She exhibited reduced arm swing and decreased pain sensation in the right side besides transcortical motor aphasia. Extrapyramidal signs or clinical criteria for dementia were absent.

Diffusion tensor MR images acquired using a sensitive-encoding head coil on a 3.0T Philips Achieva system, revealed an extensive damage in the left superior longitudinal fascicule. Moreover corpus callosum (CC) fibers showed widespread and severe disruption, which involved left premotor, supplementary motor and motor cortex connections as well as left temporal, parietal and occipital cortex connections (Figure 1). A small group of CC fibers in both brain hemispheres passing through the rostrum and the genu were preserved (Figure 1).

B. Rehabilitation Robot

The pneumatic rehabilitation robot, that is used for this study, is based on a four bar mechanism similar to the MIT-MANUS rehabilitation robot [10]. The mechanism is con-

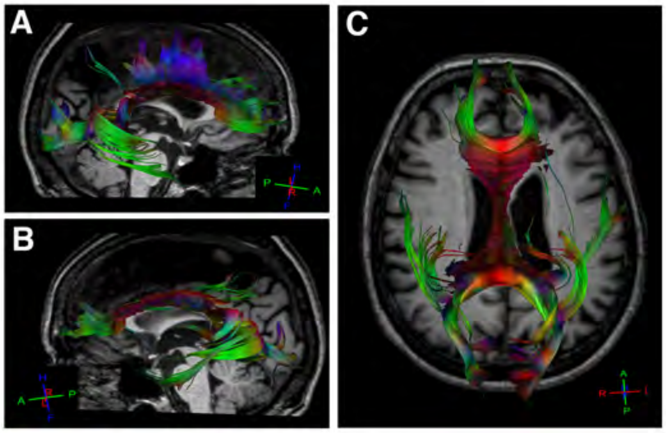


Fig. 1. Diffusion tensor tractography (DTT) for corpus callosum fibers. DTT was performed based on the connection between two regions of interest (ROI) in order to minimize the risk of including other tracks. A, Right corpus callosum fibers extended normally to frontal, temporal, parietal and occipital cortices. B, Extensive disruption of the left corpus callosum connections from the rostral CC body to the splenium. A small group of CC fibers in both brain hemispheres are preserved. C, Axial reconstructed corpus callosum fibers in the patient.

figured as a generic planar two-dimensional manipulator and optimized for delivering rehabilitation therapies, in which end-point impedance has been minimized.

The pneumatic rehabilitation robot is composed of several distinct parts as: 1) a two-dimensional manipulator fixed to a table; 2) a touchscreen computer with a custom developed software which is used as a Graphical User Interface to display activities in coordination with the robot's movement; and 3) a computer to implement real-time control of the two pneumatic actuators.

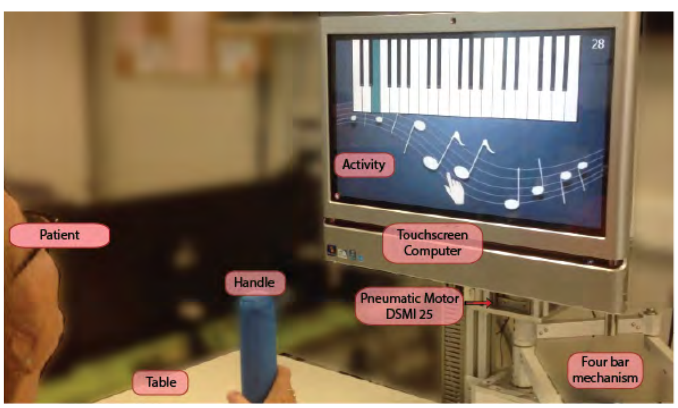
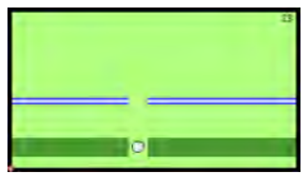


Fig. 2. Pneumatic rehabilitation robot in a therapy session

C. Therapy games

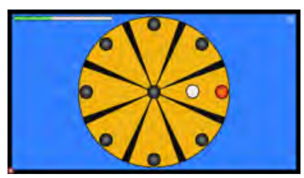
Five different activities have been used to deliver the robot-assisted therapy (see Figure 3):

- "Bar activity", in which the patient has to move horizontally to place a white ball in the hole of a bar that is moving in the screen from up to down.
- "Pac-Man activity", in which the patient has to move horizontally to place a pac-man in the hole of a column of ghosts that is moving in the screen from left to right.
- "Roulette activity", in which the patient has to perform visual-guided reaching movements from central target to one of eight peripheral targets. To do that, a center target and eight targets equally spaced around a circle are displayed on a monitor, and visual feedback regarding the current position of the robot end-effector attached to the patient's hand is provided. The direction of the illuminated target, distance, number of movements and so on can be configured for each activity.
- "Apple Tree", in which the patient has to reach apples from a tree and to fill two baskets. Moreover, a hungry bird competes with the patient to reach the apple before him/her.
- "Play the Piano", in which the patient has to play a piano. Patient should move to a central button cottoning a musical note, then a note sounds and the corresponding piano key is illuminated. After that, the patient should move to the right piano key and back to its initial position.

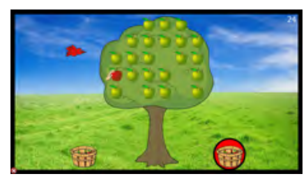


(a) Bar activity

(b) Pac-Man



(c) Roulette



(d) Apple Tree

(e) Play the Piano

Fig. 3. Activities used in the sessions of robot-assisted therapy

D. Experimental Protocol

Over a 3 months period, she has received 36 sessions of robot-assisted therapy. The duration of each session was about 45 minutes. Each session was organised in five blocks of movement training with three-minute rest periods between each block, as follows

- "Bar activity": 20 movements
- 3 minutes rest-period
- "Pac-Man": 20 movements
- 3 minutes rest-period

- “Roulette”: 20 movements
- 3 minutes rest-period
- “Apple Tree”: 20 movements
- 3 minutes rest-period
- “Play the Piano”: 30 movements

Over 36 sessions, some parameters of the activities have been changing, the most important parameter the level of assistance provided by the robot in therapy. This parameter has been changed 3 times during the 36 sessions, as follows:

- Initial value: 70% assistance.
- Value from session 6: 30% assistance.
- Value from session 10: 20% assistance.
- Value from session 20: 0% assistance.

Moreover, a test to evaluate the sensorimotor function has been carried out after each 7 sessions [11]. The test has been implemented using the Roulette activity. The patient is provided with hand position visual feedback by a white circle. Targets and feedback were presented in a screen located at 70 cm in front of the patient. Patient began each trial by holding the hand within the central target for 2000 ms. Afterwards, a peripheral target located at 10 cm from the central target, was illuminated. Then patient was given 3000 ms to complete the movement. When a target was reached, the participant had to return toward the central target in order to start a new trial. A total of 16 trials were completed and each peripheral target was illuminated in a random block design. Eight kinematic parameters have been extracted from the test trial: 1) Initial movement direction error; 2) Distance of Initial movement; 3) Initial movement ratio; 4) Path length; 5) Reaction time; 6) Movement time; 7) Maximum speed and 8) Postural speed [11].

III. EXPERIMENTAL RESULTS

A. *Sensorimotor function*

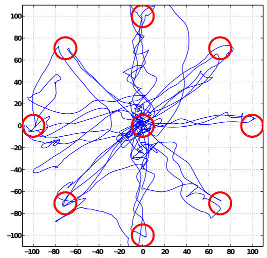
The movement trajectories from the tests to evaluate the sensorimotor function after each 7 sessions are shown in Figure 4. The figure suggests that the performance of the patient is increased from the beginning to the end of the tests as it is corroborated with the results of the eight kinematic parameters computed in each test trial.

B. *Therapy activities*

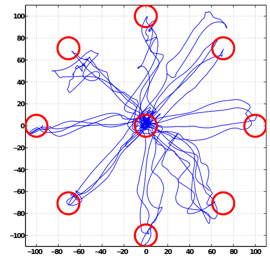
The results of the activities over 36 sessions of robotic-assisted therapy are shown in Figure 5. The success ratio for each of the five activities is shown in Figure 5(a). The success ratio has been computed as the number of therapy movements performed with success divided by the number of total therapy movements performed.

The activity time in seconds for ”Roulette”, ”Apple Tree” and ”Play the piano” activities is shown in Figure 5(b). Note that ”Bar” and ”Pac-Man” activities are not shown in Figure 5(b) since the activity time in them are not related with the user’s performance.

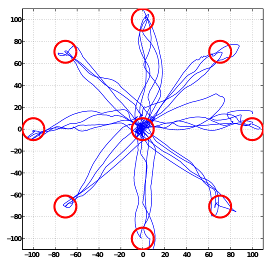
Evolution of kinematic parameters to evaluate sensorimotor function, extracted from Roulette activity over 36 therapy sessions are shown in Figure 6. Note that the peaks of Figure



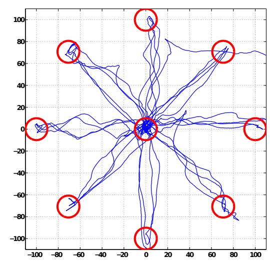
(a) Test 1. Session 7



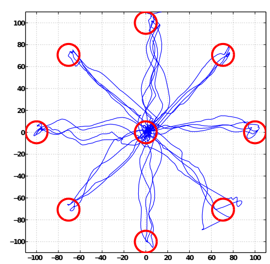
(b) Test 2. Session 14



(c) Test 3. Session 22



(d) Test 4. Session 29



(e) Test 5. Session 36

Fig. 4. Test to evaluate the sensorimotor function: Movement Trajectories

5 and 6 are due to the level of assistance. In short, the patient has no assistance from session 20.

IV. CONCLUSIONS

From our knowledge, it is the first time that robot assisted therapy is used as a rehabilitation treatment for a patient who suffer AHS. The improvements in her capability of carrying out ADL and in the control of her hand and arm are impressive despite of the progress of her neurodegenerative disease. These findings help us to explore the use of robotic technology with more patients with AHS to corroborate our results.

ACKNOWLEDGMENT

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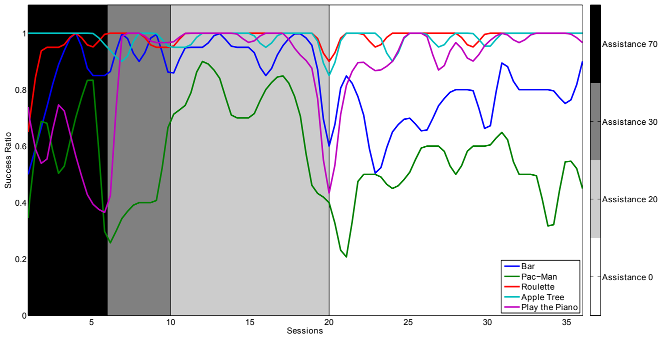
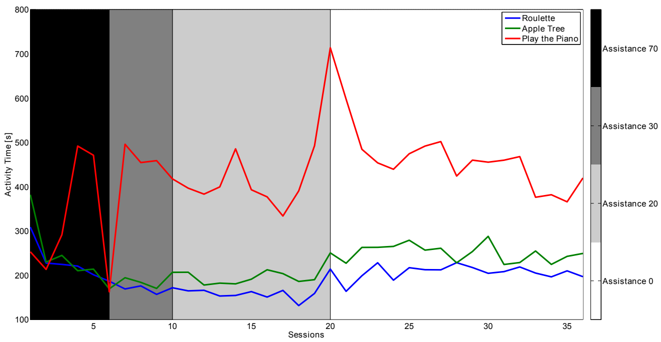


(a) Activities: Success ratio



(b) Activity time

Fig. 5. Rehabilitation Therapy: Success ratio and activity time

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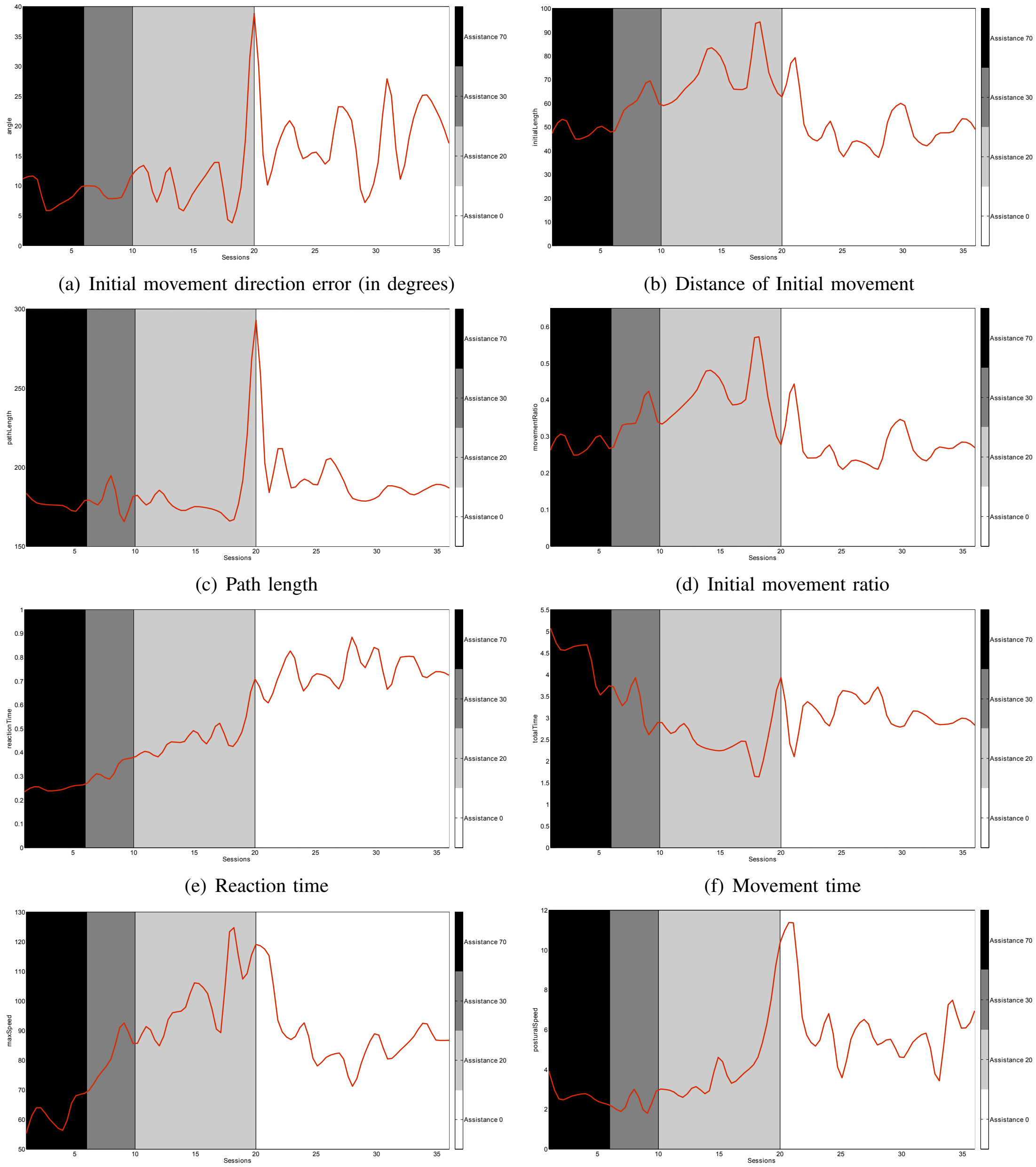

(a) Initial movement direction error (in degrees)

(b) Distance of Initial movement

(c) Path length

(d) Initial movement ratio

(e) Reaction time

(f) Movement time

(g) Maximum speed

(h) Postural speed

Fig. 6. Kinematic parameters to evaluate sensorimotor function, extracted from Roulette activity in each session.