A Follow-Up on Humanoid-Mediated Stroke Physical Rehabilitation

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ABSTRACT

We report the results of standardized tests on a single subject with a stroke at 4, 20 and 28 weeks after completion of the study. These results follow from previous work [1]. The subject demonstrated sustained improvement in motor function 28 weeks after completing the study. In addition to quantitative results, the questionnaire results by the subject and the spouse testify that the subjective user experience was also positive. This further advocates the use of general purpose robots to complement human therapists.

Categories and Subject Descriptors

J.3 [**Computer Applications**]: Life and Medical Sciences—*health*; K.4.2 [**Computers and Society**]: Social Issues—*assistive technologies for persons with disabilities*

General Terms

Experimentation, Human Factors

Keywords

Autonomous Agents, Embodied Agent, Healthcare, Physical Rehab, Stroke, Telepresence

1. INTRODUCTION

Due to the increasing number of patients and the shortage of well-trained therapists, the use of robots in rehabilitation is widely acknowledged by a research community as being a possibility. This has led to the ongoing development of diverse robotic platforms [3]. They are developed and tested in order to address specific activities and populations that meet a particular inclusion criteria. In reality, however, stroke survivors have different disabilities of varying severity depending on the site and size of lesion in the brain. Moreover, the same patient may need different types of therapy as he or she regains motor functions. Hence, in the first stage of our study, we investigate if general purpose robots can be used to provide effective stroke rehabilitation service to stroke patients rather than building multiple special purpose robots for different activities. The therapy activities that are designed by a human therapist based on her knowledge and experience are implemented in a humanoid robot. Through the results from a single case study, in our earlier work, we have shown that the fixed set of therapy activities can increase the speed of the subject's upper extremity movement [2] and therapy activities with adaptive strategy can increase not only the speed but also the range of motion of the subject's arm movement [1]. However, in order to further support the feasibility of the use of general purpose robots, we need to show that this improvement continues to be sustained and that the subjective experience of the patient and the family members are positive. Accordingly, in this paper, we report the follow-up standardized test results and the questionnaire responses of the subject and the spouse.

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2. DISCUSSION

2.1 Standardized Tests

The motor function of the subject was quantitatively measured using two standardized tests, Fugl-Meyer Assessment (FMA) and Wolf Motor Function Test (WMFT). The upper extremity portion of the FMA consists of 33 items that evaluate upper extremity functions of stroke patients. Performance on each item (e.g., Touch your ear with your weaker hand) is rated by a clinician (e.g., 0 = cannot be performed, 1 = detail partly performed, 2 = detail is performed faultlessly). The WMFT quantifies upper extremity motor ability through fifteen timed and functional tasks. The results report how fast patients achieve the tasks in addition to how many they successfully complete. Accordingly, the WMFT can measure improvements that cannot be measured in discrete scoring of the FMA. The baseline test was conducted before the study, and the additional tests are conducted 6 weeks after the study started and at the end of the 12-week study. Follow-up tests were conducted 4 weeks, 20 weeks,

Table 1: FMA results (raw scores). The three components (a, b, d) are directly related to the therapy activities that were conducted in the study. The total score reports the sum of all four upper extremity assessment components. (* indicates significant improvements from baseline at $p < .05$)

Component	Baseline	After 6 wks	After 12 wks	4-wk post-tx	20-wk post-tx	28-wk post-tx
Shoulder/elbow/forearm[a] (/36)	18	16	17	17	15	18
Wrist[b] (/10)	3	4	4	5	6	6
Hand[c] (/14)	7	6	6	6	11	12
Co-ordination/speed[d] (/6)	3	4	4	4	4	4
Total (/66)	31	30	31	32	36	40*

Table 2: Time changes in WMFT (seconds). Only the items that the patient was able to complete are presented here.

Component	Baseline	After 6 wks	After 12 wks	4-wk post-tx	20-wk post-tx	28-wk post-tx
Forearm to table	4.03	1.90	4.12	1.00	1.43	2.62
Hand to table	5.56	1.38	2.34	2.56	2.06	2.15
Reach and retrieve	5.26	1.00	2.69	1.03	0.82	1.00
Total	14.85	4.28	9.15	4.59	4.31	5.77

and 28 weeks after the completion of the study. The therapist was blind to the subject's previous scores to minimize the clinician's bias. During this follow-up period, the subject did not participate in any physical therapy activity. A Wilcoxon signed-ranks test revealed that the subject significantly improved in the FMA score from baseline to 28-week post-treatment, $Z = 2.324$, $p < .05$ (Table 1). He showed gradual improvements in the Wrist component and delayed improvements in the Hand component. The subject sustained his motor function in the WMFT throughout the follow-up period (Table 2).

2.2 Subjective Experience

At the completion of the study, we conducted a survey with the subject and the spouse. The questionnaire was constructed partially based on Weiss et al. [4]. The questions were grouped into: overall experience, feelings and impressions, comments, and future plans. Each question had a 5-point scale for response with 1 being the most negative and 5 being the most positive. The median scores from the both questionnaires were 5's, indicating that they both had good experience with the robot. They responded that the robot-mediated therapy activity was helpful, useful, pleasant, and exciting (all 5 points). Neither of them cared about the fact that the robot did not have any cosmetic features, such as hair or clothing. They were pleased with the functional features of the robot, such as arm movement. It is interesting to note that to the question 'I would rather work with clinicians than with the robot' (1 = yes, 5 = no), the subject gave a positive response (4 point) while the spouse was neutral (3 point). This indicates that the subject did not prefer a human therapist to a robot even though he had an experience with a human therapist for 1 year right after the onset of the stroke. Both the subject and the spouse replied that they would like to have a similar robot at home so that the subject could regularly exercise arm movements (5 point). They both expressed their willingness to participate further robot-mediated therapy study in the future (5 point).

3. CONCLUSION

In this paper, we report the results of the follow-up standardized tests and questionnaire responses demonstrating that both the quantitative and the qualitative experiences of the subject and the spouse were positive. This further supports the feasibility of the use of general purpose robots in stroke physical rehabilitation.

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