

Improvement in reaching kinematics from training in a mixed reality stroke rehabilitation environment

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1. INTRODUCTION

This abstract is part of a coordinated submission to the Workshop on Media Arts, Science, and Technology of complementary posters on a mixed reality stroke rehabilitation system developed at the Arts, Media and Engineering Department at Arizona State University. This poster will show pilot results from three mild to moderate stroke patients with residual functional disability in their affected arm after training with this system. This poster will only address the clinical and kinematic results but technical details about the components of the system can be found in the MAST '09 abstracts/posters entitled: "Interactive Visual Feedback for Mixed Reality Stroke Rehabilitation", "Parametric Musical Sonification for Mixed Reality Stroke Rehabilitation", and "Media Adaptation Framework for Mixed Reality Stroke Rehabilitation." Work on a developing a low-cost, portable version of this system for use in the home is presented in: "Low cost home system for assessment and rehabilitation of stroke." A full summary of the system can be found in the abstract/poster: "Integrating Arts and Computation in Mixed Reality Stroke Rehabilitation."

2. BACKGROUND

Stroke is the leading cause of adult disability in the United States. While a stroke can affect each individual in a different way, a common long-lasting result is upper-limb disabilities on the affected side of the body. Physical therapy and repetitive exercise have been shown to improve functional recovery of movement in these patients. Increased cognitive and physical engagement of the patient in their therapy enhances the effect of the training. Training must address both performance of low level movement features as well as development of high level movement strategies. The therapy process needs to also account for boredom during repetitive exercises and discomfort due to compensatory strategies or non-use effects. Our goal is to create a system, targeted towards chronic patients that provide an engaging and effective way to practice and improve reaching movement. This system incorporates concepts from motor learning, dance, music, visual art, computing, engineering and physical therapy. It provides audio, visual and tangible feedback that guides patients' movements to become smoother, more efficient and closer to movement patterns used prior to the stroke. This feedback is based on precise kinematic features extracted from motion capture data, which allows it to be presented at real-time during the movement. The feedback and task can also be dynamically adjusted to adapt to the patient's abilities, mental capabilities and personal preferences.

3. METHODS

Three chronic stroke patients were recruited to participate in our pilot study of the mixed reality system. Each patient came in for two evaluation visits before training, six visits to complete training with the system, and two evaluation visits after training. This poster will focus on comparisons between the evaluation visits directly before and after the training sessions. During the evaluation visits, patients performed the Wolf Motor Function Test (WMFT), the Systematic Test to Assess Reaching Times (START), completed the Stroke Impact Scale (SIS) and Motor Activity Log (MAL) and performed reaches to a physical target. During the reaches to the physical target, motion capture data from the patient's affected limb and their torso were recorded. The target locations were: SI (supported reach, placed ipsilateral to affected arm), SM (supported reach, placed at the patient's midline), AGI (against gravity reach, placed ipsilateral to affected arm) and AGM (against gravity reach, placed at the patient's midline). Data were also recorded from the physical target, which is covered in force sensitive resistors.

Kinematic parameters were calculated from the motion capture data during the physical target reaches. These parameters, such as joint coordination, velocity of the hand and torso compensation, are all parameters that were addressed during the training sessions. The data from the physical target reaching from the pre-training evaluation visits and post-training evaluation visits were compared to determine if the training had significantly improved the subject's kinematic features. Results from the clinical tests and surveys (WMFT, SIS and MAL) were also compared before and after training to find significant differences.

4. RESULTS

Because the system is adaptable to each patient, and each patient had unique movement patterns and deficits, the training sessions for each patient was customized directly to their needs and progress. All results will be presented for the individual patient in the context of their movement profile.

The clinical surveys and tests did not show dramatic results when compared before and after training with our system. However, these tests are generally used as indicators of more general, long-term performance thus no major differences were expected after only two weeks of training. There were increases for the MAL and SIS in 2 of 3 patients, which shows training with our system did not hinder their recovery.

The analysis of the kinematic features showed more meaningful results. Each patient showed improvements in areas that they had presented considerable problems in their movements, and in turn,

in areas where the system had focused their training. Patient training profiles are as follows:

- Subject 1 worked mainly on increasing his reaching speed, reducing jerk, and improving the bellness (smoother acceleration and deceleration during reaching) and the consistency of his velocity profile. He also worked on reducing torso compensation at the end stage of the reach.
- Subject 2 mainly worked on increasing his reaching speed and becoming more consistent in his reach. He also worked on relaxing his elbow and shoulder before the movement started and synchronizing his shoulder

and elbow joints during the reach to improve his trajectory and target acquisition accuracy.

- Subject 3 mainly worked on reducing her amount of shoulder and torso compensation and to increase her elbow openness while improving joint synchrony.

Figures 1-3 show representative improved movement parameters for each subject.

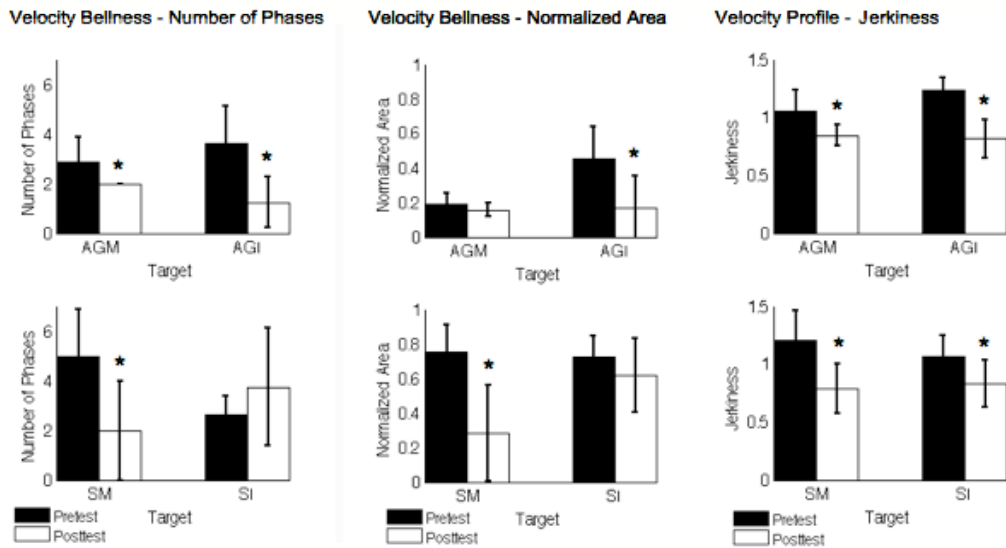


Figure 1. Velocity results for Patient 1. An asterisk indicates a significant ($p < .05$) improvement for that parameter.

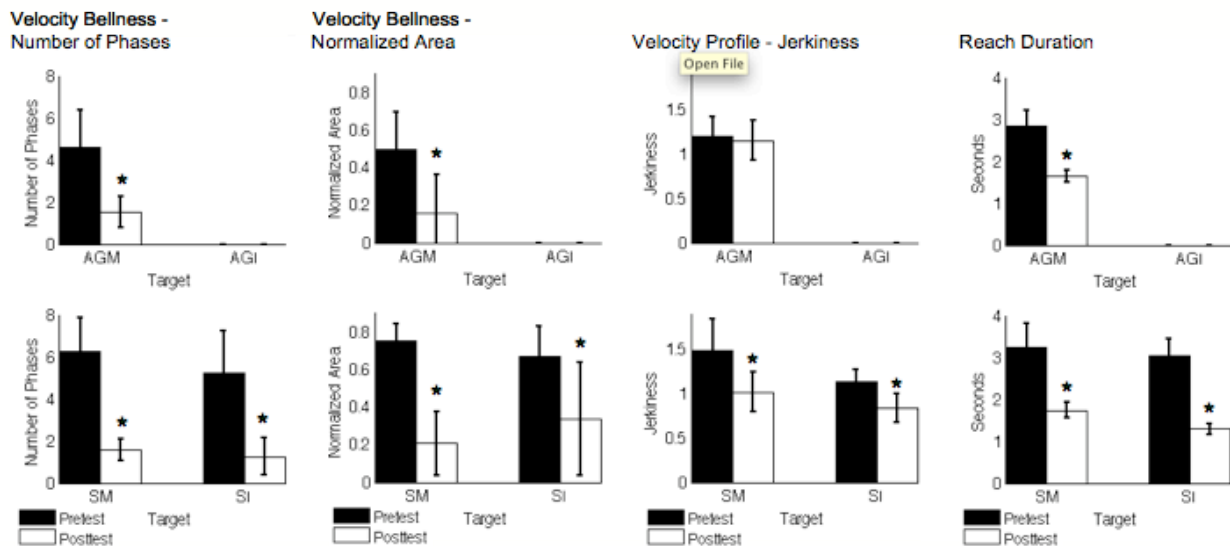


Figure 2. Velocity results for Patient 2. An asterisk indicates a significant ($p < .05$) improvement for that parameter. Patient 2 had missing data from target AGI so those results are not shown.

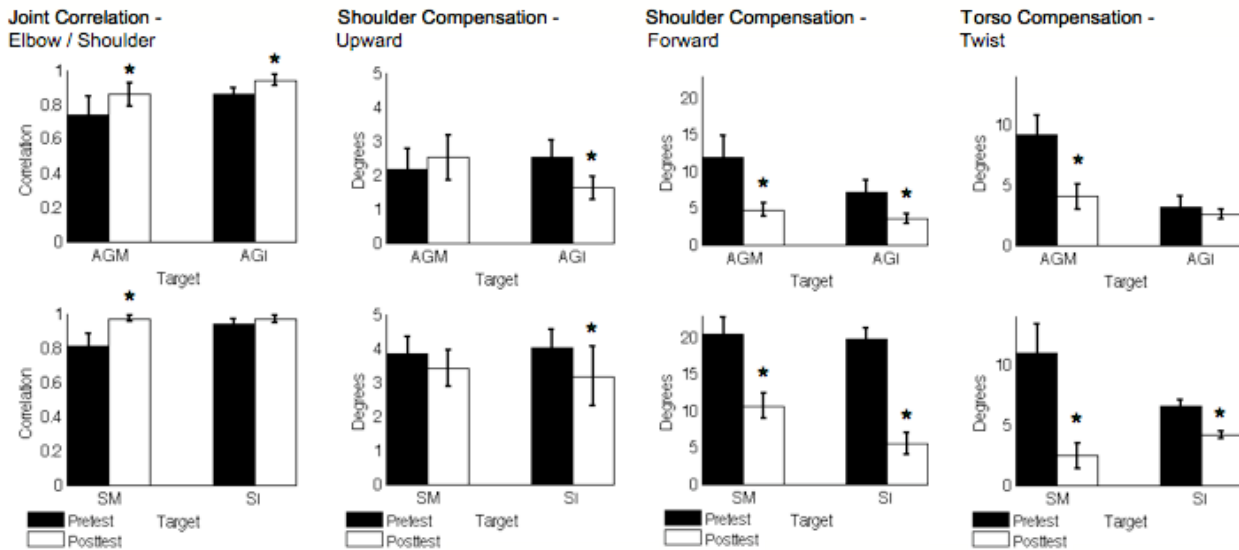


Figure 3. Joint correlation and compensation results for Patient 3. An asterisk indicates a significant ($p < .05$) improvement for that parameter.

5. DISCUSSION

We believe that since reaching kinematics were improved and recovery was not negatively affected, as shown by the functional clinical scales, our study offers “proof of principle” in applying this technology to the rehabilitation of subjects who have mild-to-moderate hemiparesis resulting from stroke. We were able to fine-tune our feedback parameters to communicate intuitively to the subjects measures of performance and direction for improvement, as well as successfully integrating hybrid (physical-virtual) environments to bridge motor learning in the virtual and physical world. Improvements made using the virtual and hybrid environments successfully transferred to physical reaching and patients improved at four different targets, (supported and against gravity to locations ipsilateral to the affected side and at the midline) pointing to the potential of the system for promoting generalizable learning.

Each patient showed significant improvements in their reaching kinematics, specifically in areas where their training was focused, i.e. what aspects of the arm kinematics were used to generate feedback. Other studies [1,2,3] have shown improvements using constraints of the unimpaired limb, robotic assistive devices or trunk restraints. However, all of these methods use external interventions that force the subject to move in a certain way. Our system takes a completely different approach of allowing the subject to be completely unencumbered and free to move naturally, and providing incentives to patient to move in a more efficient way and deterrents from using compensatory or inefficient movements. This allows the patient to actively, yet often subconsciously, construct his or her own strategies in a way that that does not require any physical interference with the subject’s limbs or torso. Our system also trains the subjects in a way that they

progressively integrate the improved kinematics they learn for each parameter to form a complete strategy instead of focusing only improving each parameter separately. The system also effectively trains the subject to integrate the motor tasks with input from their audio, visual and tangible sensory streams which could promote increased motor learning and neural plasticity.

6. CONCLUSION

The presented study has successfully shown a proof of principle that an adaptive mixed reality rehabilitation system can provide a customized reaching and grasping training program to chronic stroke patients and elicit improvements in important movement parameters. We believe this system can be a useful tool to therapists in structuring therapy based on kinematic parameters and helping them to target specific areas of the movement with engaging audio and visual feedback.

7. REFERENCES

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- [2] S.M. Michaelsen, R. Dannenbaum and M.F. Levin, “Task-specific training with trunk restraint on arm recovery in stroke: randomized control trial,” *Stroke*, vol. 37, pp. 186-92, Dec 8, 2005.
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