A Novel Framework for Optimizing Motor (Re)-learning with a Robotic Exoskeleton

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Conventional therapies for stroke rehabilitation have failed to provide reliable recovery and thus a majority of subjects are left with severe impairments, unable to accomplish activities of daily living. A number of robots have been developed to assist in the rehabilitation process, but the results with robots have been no better than those achieved with manual therapy [1]. This is because the current robot-assisted therapy programs are based on manual therapies and make limited use of the evidence-based understanding of motor learning and neuro-rehabilitation. A critical question to be answered to improve robotic rehabilitation is what is the optimal rehabilitation environment for a subject that will facilitate maximum recovery during therapy.

Our idea is to first understand the key factors that affect motor learning and neuromuscular rehabilitation and then incorporate those in the robot control algorithm to give rise to a rehabilitation environment that is optimized for each subject and is adaptively tailored based on his or her performance and needs. 'Challenge Point Hypothesis' and also experiments suggest that optimal learning occurs when the challenge is suited to the participant proficiency [2]. Challenge in robotic rehabilitation has so far been modulated by adjusting the amount of assistance provided by the robot during therapy. However, experiments show limited success of this approach as just adjusting assistance may not be sufficient to affect true recovery. Literature shows that task variability (Practice variability hypothesis) and augmented feedback also improve motor learning and therefore can be used to modulate challenge.

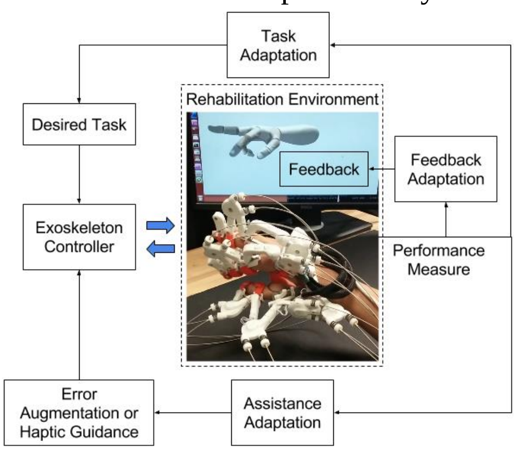

Figure 1: An overview of the proposed controls framework for robot-assisted rehabilitation.

We present a framework for performance-based modulation of challenge in this multi-dimensional space (task, assistance and feedback) on motor learning and re-learning during rehabilitation. The framework is designed around the idea of providing an optimum rehabilitation environment to each subject by adapting the environment variables to provide a challenge level commensurate with the level of the skill of the subject. The rehabilitation environment consists of a human subject performing a functional task with UT hand exoskeleton, while the framework provides some form of feedback (e.g. verbal, visual, or auditory) (Fig. 1). The performance on the task is assessed using measures that estimate the level of skill of the subject. The framework consists of continuous adaptation along the following three dimensions based on the performance of the subject on a functional task: i) task frequency and amplitude adaptation to introduce sufficient variability in the task for keeping the task optimally challenging based on the skill level of the subject, ii) assistance adaptation to provide a haptic guidance or an error augmentation training while smoothly transiting between the two based on the subject's skill level, and (iii) feedback adaptation to provide just the right amount of feedback to avoid reliance on feedback and instead encourage motor adaptation and learning. Our ongoing work focuses on testing hypotheses to examine the efficacy of this multi-modal challenge modulation for different tasks.

References

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2. Guadagnoli MA and Lee TD (2004) Challenge point: a frame. for con. J. Mot. Behav. 36(2):212–224.

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