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Modulating Robotic Assistance with Machine Learning to Enhance Motor Skill Training

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Abstract

Despite the routine clinical use of robots for training neurologically injured patients, current robots are limited at supporting patients in regaining the functional movements needed to perform activities of daily living. This limitation could be due to the neglect of somatic (tactile and proprioceptive) aspects when training within virtual training environments during conventional robotic neurorehabilitation. Somatosensory information (e.g., the interaction forces with tangible virtual objects), which is necessary to achieve skillful movements, could potentially also be provided by robots through *haptic rendering* -i.e., the simulation of interactive forces with virtual elements. However, robotic assistance (e.g., supporting patients' arm weight) necessary to physically assist stroke patients during movement training might deteriorate the perception of the haptic rendering forces, and therefore, limit their potential to enhance motor learning. Thus, robots should limit their assistance by adapting the assistance level to the individual's ongoing performance to optimize motor learning.

Within this project, we designed a virtual training environment that integrates robotic haptic rendering to develop adaptive assistance algorithms in our upper limb exoskeleton robot. In a first step, we run an experiment with 40 healthy participants to investigate the effect of haptic rendering and arm weigh support assistance (supporting 100% of participants' arm weight) on motor learning. The motor task consisted of inverting a virtual pendulum, whose dynamics were haptically rendered at the robot hand-module. We found that while haptic rendering enhanced motor learning and promoted transfer-learning, supporting 100% of the participants' arm weight hampered motor learning. Further, analysis of participants' movements during training revealed that participants who trained with haptic rendering covered more workspace with their hands and moved faster than participants who trained without haptics.

During this first experiment, we also collected performance data on a second day when participants performed the task with randomized arm weight support levels (between 0, i.e., no support, and 100% support). These data will be employed in the project's second step, where we will use machine learning methods to build and test a model that selects the optimum arm weight support level based on the participants' ongoing performance. The model's effectiveness will be evaluated with new participants and compared to the results obtained from the first experiment (i.e., the participants who had no arm support or 100% fixed support during training).

The application of machine learning is a promising approach to enhance motor learning and neurorehabilitation. Data science in robotic neurorehabilitation has the potential to accelerate the motor recovery of neurologically injured patients by means of personalized training.