Book of Abstracts

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A neuromusculoskeletal model of spinal reflexes during posture control

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During posture control tasks, feedback from muscle afferents allows humans to compensate for unpredictable mechanical disturbances acting on the body. Recently, an identification method was presented to accurately describe the human controller with a small set of parameters that characterize the spinal feedback loop, called reflex gains [5]. These reflex gains represent the amount of positional, velocity and force feedback from muscle afferents present in the control action. These methods have shown that humans adapt their reflexive settings, depending on task instruction [1] and mechanical properties of the haptic manipulator they interact with [3].

Although these reflex gains are well-suited for describing the human control system from a control engineering perspective, they have only limited meaning in terms of physiology. The goal of this study is to link measured reflex gains to their underlying neural, sensory and muscular mechanisms in the central nervous system.

A biologically realistic neuromusculoskeletal model was built, where an antagonistic pair of muscles actuates a limb, while being controlled by a model of the spinal cord circuitry [4]. The spinal cord circuitry is provided with input from muscle afferents (muscle spindles and Golgi tendon organs) and tonic descending input. The neural network model comprises 2298 spiking neurons in 6 populations, i.e., motoneurons, Renshaw cells, group Ia, group Ib, excitatory and inhibitory interneurons. The neural properties and synaptic weights were taken from literature [2]. No training was performed on the synaptic weights. To mimic the in vivo experiments on humans, the endpoint of the limb is disturbed with force perturbations. The same identification techniques as used with the in vivo experiments were used on the simulated experiments, to obtain the reflex gains describing the human control system.

A sensitivity analysis was performed on the neuronal model, determining the influence of all individual neural, sensory and synaptic parameters on the resulting reflex gains. Amongst the more predictable results are the strong effects that motoneuron properties, co-contraction, Ia afferent velocity feedback and Ib afferent force feedback have on motor behavior. More interesting is that the effect of group II afferent input on motor output was marginal in these simulations and that co-contraction, besides the viscoelastic properties, also strongly affects the reflex gains, by bringing the motoneurons in a more input-sensitive state. The method presented here will be used for further investigation of the inner workings of the human motor control system, and its effect on limb dynamics as experimentally measured.

References

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The neuromuscular control of voluntary fall techniques during a fall

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Recently, the practice of fall techniques has been introduced in short-term fall prevention exercise programs for the elderly [1]. However, it is not clear yet whether such training would enable people to apply these techniques during a real-life fall. In order to provide more insight into this issue, it would be helpful to know how much time it takes to initiate and to successfully execute such techniques. In addition, it would also be important to know whether these techniques can be performed in a correct manner, without having extensive experience in martial arts. The aim of this study was to investigate the neuromuscular control of voluntary fall techniques in inexperienced as well as in experienced fallers.

Participants were 14 young women (age 21-35 years), of whom 5 were seasoned (> 19 years of experience) judokas. The remaining 9 participants (non-judokas) were administered a 30-minutes training session in martial arts (MA) fall techniques. Participants started from a kneeling position with a lateral inclination of 21°, holding on to a grip. After release, they received an auditory cue (at delays of 1, 40, or 80 ms), prompting either a natural fall arrest with the outstretched arm (block) or an MA fall. EMG-data of shoulder and trunk muscles were collected.

Mean fall duration was 405 ms. Participants successfully applied the requested technique in 85% of the trials. In the 80 ms delay condition success rates were lower than in the 1 ms and 40 ms delay conditions. There were no significant experience-related differences in success rates. In response to the cue, technique-specific EMG activity could be observed after 180-190 ms in left posterior deltoid, trapezius,