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Modular Organization of Motor Control during Dynamic Tasks

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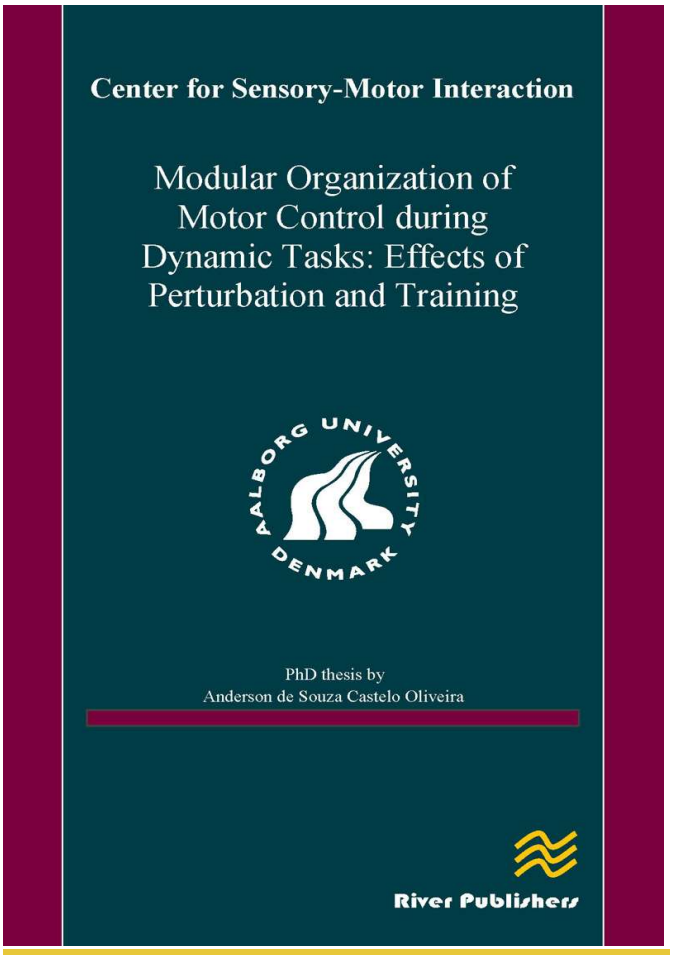
Human locomotion is characterized by an apparently complex control of many degrees of freedom. It has been suggested that the central nervous system optimizes muscle recruitment by using muscle synergies or motor modules, which are investigated by using non-negative matrix factorization of the EMG signals. Human bipedalism increases instability and the specific mechanisms involved in balance control during locomotion are well known, but the general control of human locomotion during perturbed conditions is only partially investigated.

This PhD thesis focuses on the modular control of locomotion and the effects of perturbations to balance on the neuromuscular control and biomechanics in different locomotor tasks. Moreover, it investigates the effects of balance training on the neural control of complex motor tasks under perturbed conditions. Using perturbations during walking, it was first investigated whether perturbations experienced among unperturbed trials would change motor control strategies during walking. The work demonstrated that the awareness of the possible perturbations did not affect motor behavior substantially. In terms of perturbations, it was found that the modular organization from unperturbed walking was preserved during perturbed walking and the most relevant changes were verified in the timing to activate motor modules, most likely as a response to strong afferent inputs caused by perturbations.

By using complex locomotor tasks (i.e., fast changes in direction while running), it was also verified that such tasks are also modular, showing impulsive burst-like activation signals to control motor modules that are similar to those found during walking and running. Perturbations elicited at initial contact during fast changes in direction evoked changes in the activation timing of the motor modules, which is consistent to the findings from the walking study of the PhD work. Observations on peripheral changes related to perturbations motivated the conduction of two additional studies involving balance training. It was observed that six weeks of unilateral balance training enhances postural responses to sudden perturbations during a single-limb standing position. A similar modular organization to perform fast changes in direction after training was found, however, specific changes in specific motor modules demonstrated an increased co-contraction at the hip and knee, upregulating joint stability during perturbations.

These results together indicate that perturbations to balance during locomotion may influence specific components within the modular organization. Balance training may be effective in improving inter-muscular coordination and with the mechanical stability in order to increase protection during unexpected slips.



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