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Neural control of postural responses during perturbations to balance while changing direction

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Introduction: The neural control of locomotion has been studied from various perspectives. The mechanical requirement is to control a large number of muscles executing movements of a body system with a limited number of degrees of freedom during motion. A highly sophisticated muscular recruitment strategy may be required. This general control task can also be viewed as a dimensionality problem where the central nervous system may recruit muscles in a synergistic manner, reducing the computational load to a modular and low-dimensional set of inputs to the muscles – called motor modules. Motor modules are a set of muscles that are synchronously recruited in a time-invariant manner. This model has been widely used to describe the neural control of walking and running by a set of four to six motor modules (Lacquaniti et al. 2012). More recently, this model was successfully applied to perturbed gait, demonstrating that postural responses to perturbations can be achieved with no substantial changes in the motor modules (Oliveira et al., 2012). On the other hand, the timing to activate motor modules was drastically altered, which suggests influence of afferent inputs on the integration of supraspinal commands to the muscles. However, little is known about the postural control during complex locomotor tasks, such as cutting manoeuvres. Therefore, this study aimed to investigate whether the modular control of complex locomotor tasks is influenced by perturbations to balance.

Methods: Twenty-two healthy men performed 90° unper-turbed cutting manoeu-vres while running (UPT) as well as manoeuvres perturbed at initial contact (PTB, 10 cm translation of a moveable force platform). Surface EMG activity from 16 muscles of the supporting limb and trunk, kinematics, and ground reaction forces were recorded. Motor modules and their respective temporal activations were extracted from the EMG signals by non-negative matrix factorization. Similarities between UPT and PTB were computed for motor modules and activation signals (ranging from 0 to 1). Knee joint moments, co-contraction ratios (CCR) and co-contraction indexes (CCI, hamstrings/quadriceps) and motor modules were compared between UPT and PTB.

Results and Discussion: A low-dimensional set of five motor modules was sufficient to reconstruct UPT and PTB EMG activity (variation accounted for [VAF]=0.91±0.05). Moreover, no changes were found in the motor modules responsible for the modulation of UPT and PTB (similarity=0.83±0.08, Figure 1), but the activation signals that drive the temporal properties of the modulation were influenced by perturbations (similarity=0.71±0.18), which may suggest that afferent inputs from perturbations are altering the timing to recruit motor modules. Perturbations at initial contact reduced knee abduction moment (7%), as well as CCR (11%) and CCI (12%) shortly after the perturbation onset. These changes in CCI and CCR were caused by a reduced activation of hamstrings that was also verified in the activation signals of the specific motor module related to initial contact.

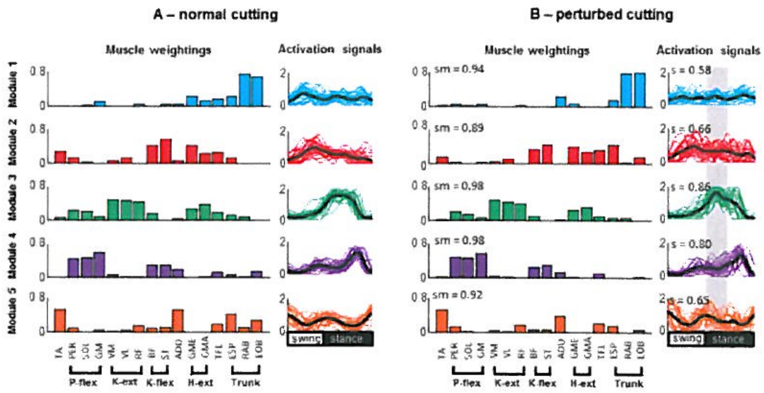

Figure 1: Motor modules that describe modular control of unperturbed (A) and perturbed cutting manoeuvres (B).

Conclusion: Our results suggest that perturbations to balance influence afferent inputs to the motor patterns, altering temporal properties of muscle recruitment. Changes in neural control were reflected in reduced joint stability at the perturbation event, consequently the protection from neural mechanisms is reduced and injury risk might be increased in cases with more drastic perturbations.

References:

Lacquaniti et al., J Physiol 590:2189-2199, 2012.

Oliveira et al., J Neurophysiol 108:1895-1906, 2012.