Abstract

The recording of biopotentials such as electroencephalographic (EEG) and electromyographic (EMG) signals during motor actions is an effective approach to non-invasively track the physiological processes concerning sensorimotor integration. The neural encoding of afferent and efferent information has been widely investigated by means of outcome measures such as corticomuscular (CMC) and corticokinematic (CKC) coherence, evoked and induced EEG responses to stimuli provided in quasi-static conditions. However, the study of brain signals during movements is still strongly limited by bulky and wired technology, thus hindering the comprehensive investigation of the EEG signal properties and characteristics in dynamic conditions. With the long-term aim to apply cortical research to real-world-like scenarios, i.e. in everyday situations, the aim of this dissertation was the design, characterization and experimental application innovative technologies for the study of biopotentials in the context of the sensorimotor integration studies. To this purpose, the current bottlenecks limiting the EEG signal acquisition during movements were firstly identified and modelled. This operation led to the definition of possible technological solutions that were subsequently prototyped to overcome the highlighted limitations. Specifically, a miniaturized system to enable the wireless, unconstrained recording of EEG signals was designed and successfully validated against a well-established system under conventional, static conditions. Additionally, original EEG electrodes systems were designed with the aim of investigating the contribution of connecting cables and electrodes technology to the genesis of motion artifacts compromising the EEG signals quality. In the second part of the thesis, the developed wireless EEG system was applied in both static and dynamic physiological contexts. Firstly, the effect of a voluntary muscular contraction on cortical processing of naturalistic proprioceptive stimulation was evaluated. Secondly, the brain-periphery coupling was investigated during walking, jogging and cross-country skiing. These studies were performed to explore the possibility to effectively monitor the processing of afferent and efferent information occurring at the level of the primary sensorimotor cortex during movements. Overall, the presented studies showed promising results to extend EEG research to wide contexts, opening new frontiers to examine the physiological and pathological human sensorimotor system during naturalistic conditions.
Keywords: wireless EEG, biopotential signal acquisition, proprioception, sensorimotor integration, motor cortex, the brain