

Referent Coordinates for Action and Perception

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The theory of movement control with neural variables representing spatial referent coordinates (RC) for effectors has evolved from the classical equilibrium-point hypothesis [1,2]. It has been developed to account for a variety of experimental observations including patterns of neuronal population activity, stabilization of salient performance variables, intentional and unintentional actions, and movement disorders in neurological patients. This approach views kinesthetic perception as a result of interaction between RC and signals from peripheral sensory endings that are used to estimate deviation of the state of the effector from the RC. The abundance of signals contributing to kinesthetic perception, in combination with stability of percepts, suggests the existence of stable manifolds within the high-dimensional space of efferent and afferent variables. Several recent experiments motivated by this theoretical approach have suggested that RC participating in the perceptual process is not always equal to its counterpart generated to produce action. The difference between RC-action and RC-perception (the latter can be addressed as *efference copy* of RC-action) leads to a number of consistent errors in force-matching tasks between the two hands and verbal reports using psychophysical scales. In particular, when healthy persons are asked to co-activate agonist-antagonist muscles without changing the resultant force produced by the hand, they show an unintentional large force increase, report verbally a force drop, but match the increased force relatively accurately with the contralateral hand [3]. A series of experiments quantified unintentional force drifts and force matching with and without vibration applied to the agonist or antagonist muscles [4]. These studies have suggested that distorted copies of the RC to the task-hand were used during force matching. Such distortions emerged spontaneously and could be amplified by the response of sensory endings to muscle vibration combined over both agonist and antagonist muscle groups. In particular, using distorted copies of the RC for the antagonist muscle group was likely to lead to the observed behaviors. Taken together, these and other studies suggest that participation of the action-related neural processes in perception can involve distortions of the RC values. In other words, efference copy is not always a copy of the efferent process [5].

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