Multi-element synergy and its modulation in human movements : concept and application to sport activities

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ABSTRACT

In many of the daily body activities, we utilize two or more effectors (e.g., a set of fingers, joints, etc) together to achieve desired actions. The use of multi-effectors implies that the individual effectors involved in tasks work together for the successful completion of the tasks. In this regard, the human hand with fingers is an excellent example of kinetic and kinematic redundancy. The redundancy implies that the number of elements is larger than the number of constraints; thus, solution families can equally satisfy given motor tasks. It has been proposed that the organization of solution families for stable performance is a strategy used by a neural structure, which has been termed as "synergies." Recently, a computational approach to the coordinated behaviors of multi-elements has been proposed at a different level of analysis (e.g., joint, end-effector force, electromyography, motor unit). The main idea of this approach is that the controller may actively use a redundant set of elements resulting in solution families, and the idea is associated with the principle of motor abundance. It has been revealed that synergic actions in the redundant human system are modulated in a feed-forward manner. Stability in the human movement system refers to an ability to stabilize important performance variables in task-specific ways by organizing multi-elements in the system. Thus, "good" stability of the human movement system implies "good" ability for stabilizing the system against perturbations, which well fits with the classical definition of stability. Indeed, a human being has an ability to adjust a certain neural-related variable(s) or to make a subtle change in a performance variable prior to a virtually detectable action if one knows in advance the information of "when" and "what" for the upcoming tasks, and this phenomenon has been termed as anticipatory synergy adjustments (ASAs). Recent experiments have shown that the purpose of ASAs is to attenuate the strength of synergies prior to quick voluntary actions (i.e., rapid changes in net performance). It is assumed that the attenuation of the synergy is a purposeful destabilization of the performance in order not to compete for its synergy during a quick change of salient performance variables. For a healthy young group, a drop in the synergy index started about -200 ~ -300 ms with respect to the initiation time for the apparent change in the performance. The activation time of ASAs is delayed with aging, fatigue, vibration, and neurological disorders including Parkinson's disease, and cortical stroke. However, there was no difference in the time of ASAs after the training, various action directions, and men vs. women. In addition, earlier studies reported parallel changes in the synergy indices and ASA with various populations and treatments including the aged group. Further, we have applied the concept of synergy for sports activities. In particular, hand/finger actions are a critical factor for archery performance. The current experiments as to the simulated archery performance showed 1) the performance accuracy and precision was better when the subjects were allowed using all four fingers than using a smaller number of fingers. Also, the synergy indices (i.e., stability) increased with an active number of fingers. 2) The precision of the performance (i.e., consistency) was larger when the time of force release was set by the subjects than when the release time was given externally. The current experimental outcomes shed light on the mechanism of control procedure in sports activities with the help of the concept of synergy.

Future studies will have to ascertain and configure the framework of synergy in various sports performances in which different sets of bodies are involved.

Keywords: Synergy, Anticipatory synergy adjustment, Hand/fingers

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