Phase-dependent encoding of motor memory

*Yuto Makino[1], Masaya Hirashima[1]

1. National Institute of Information and Communications Technology

Motor behaviors are highly flexible across temporal and spatial scales. For example, when writing a letter, its geometric pattern is preserved despite variations in scale and speed (Viviani & Terzuolo, 1980). Such flexibility cannot be fully explained by internal representations based on movement states (Sing et al., 2009) or absolute time. Instead, the brain may rely on a more abstract representation that captures the temporal progression relative to its overall structure. Here, we propose the existence of phase-dependent motor primitives, where phase defines the normalized temporal position within a movement. In Experiment 1, participants adapted to an S-shaped force during an 8 cm (or 16 cm) reach, where the force reversed midway. They then produced similar force patterns in untrained 16 cm (or 8 cm) reaches. This generalization cannot be explained by movement states alone, suggesting the involvement of an abstract feature such as phase, which, in a single reach, is difficult to separate from acceleration. In Experiment 2, we dissociated phase from acceleration using a double-reach task. Opposing force fields were applied to either the first or second half of the overall movement. If the same motor primitives had been engaged in both halves, interference would be expected. However, participants successfully learned both fields, suggesting a separation of motor primitives between the first and second halves of the movement. In Experiment 3, we used a button–reach–button task to dissociate the reach phase within the overall movement sequence from the ordinal position of the reach itself. Participants learned opposing force fields depending on phase (at one-quarter vs. three-quarters in the overall movement). Since the reach was always the second action, the observed separation of motor primitives must be attributed to its phase within the overall sequence. These results suggest that internal models are organized according to phase within a unified motor sequence.

Keywords: Motor learning, Phase , Motor primitives