早稲田大学審査学位論文

博士（スポーツ科学）

概要書

Structure of Motor Programming: Inference from Event-related Potentials

運動プログラミングの構造 －事象関連電位による検討－

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To produce actions, our brain sends appropriate motor commands to synchronize the contractions and relaxations of relevant muscles. These commands consist of both spatial and temporal parameters necessary for movement execution. The specification of such motor commands is widely believed to be controlled by a central motor program.

The purpose of the present study was (1) to investigate how different motor parameters are organized during motor programming, whether it is a unitary stage with interactions between different kinds of parameters or whether each parameter is set independently of the others; (2) to confirm the functional loci of motor parameters during motoric processing; (3) to reveal the underlying neural mechanism of motor parameter specification.

Firstly, three experiments adopting the additive factor method (AFM) logic were conducted to confirm potential motor related parameters suggested by previous studies. Participants performed choice reaction time tasks in all the three experiments, in which they responded to the stimuli for the left and right by tapping their left or right fingers, respectively, with different movement duration (short or long), hand placement (crossed or uncrossed), or response sequence complexity (simple or complex). Three pairs of these parameters were orthogonally manipulated (experiment 1: movement duration and hand placement; experiment 2 and 3: movement duration and response sequence complexity). All factors yielded main effects on reaction time (RT) but no interactions. These findings suggested the existence of separable independent substages associated with motor programming processes.

Secondly, besides behavioral data, psychophysiological evidence (event-related potentials, ERPs) was collected in two succeeding experiments. Participants performed choice reaction time tasks in both experiments, in which they responded to the stimuli for the left and right by tapping their left or right fingers, respectively, with different hand placement (crossed or uncrossed) and response sequence

length (one or three) (experiment 4), or response sequence complexity (simple or complex) and movement duration (short or long) (experiment 5). All factors yielded main effects on reaction time but no interactions, supporting the existence of independent substages suggested by experiment 1, 2 and 3. Moreover, since the lateralized readiness potential (LRP) is considered to be an index of hand-specific response activation and functional loused at the beginning of motor programming. Additive effects of both pairs of parameters on the onsets of response-, but not stimulus-synchronized LRPs, suggest motoric loci of those parameters. Moreover, these findings are at variance with the notion of a unitary movement programming stage.

Last, experiment 6 adopted a precue paradigm in a force production task to reveal the underlying neural mechanism of motor parameter specification. The precue stimulus provided the participants with information about both the response finger (right or left) and the required target force (4 N, 10 N, or 16 N). The participants were instructed to produce the target force of 10 N in the single-target task and to produce three different target forces in the multiple-target task. The late contingent negative variation (CNV) amplitude was larger in the multiple- than single-target task, even though the same target force (10 N) trials were compared across the two tasks. In contrast, the foreperiod LRPs did not differ between tasks. Since the CNV represents motor programming at a central level, it implies that force parameter specification is reflected by the CNV at a central level, rather than by the LRP at a peripheral level.

In conclusion, the present study suggests that (1) motor programming stage consists of separable independent substages associated with various motor parameters; (2) functional loci of these motor parameters are in motoric processes after response hand selection; (3) specification of such motor parameters occurs at a central rather than peripheral level.