Learning of skilled behavior

Stabilization of arm configuration and muscle activity patterns during cycling arm movements against external resistances

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Limb movement patterns and their variances likely depend on environmental forces. We investigated a task when the variance of the endpoint trajectory (hand path) is assumed to be very small. The question is, how arm configuration- and muscle activity variances are influenced by external resistances.
Seventeen right-handed, able-bodied participants performed arm cycling movements under three resistance conditions: low, moderate, high crank resistance on a MEYRA (Kalletal, Germany) ergometer. EMGs were recorded from biceps (BI), triceps (TR), delta anterior (DA), delta posterior (DP). Positions of markers placed on the participant's arm and on the ergometer's crank were recorded by a ZEBRIS (Isny Germany) movement analyzer. The intersegmental angle between the upper- and lower arm was computed from marker positions. Time courses of joint angles and muscle activities (EMG amplitude) were segmented based on the number of cycles the subjects completed. The frames in which the elbow reached the most flexed positions were used to define the starts of separate cycles. The time required to complete one cycle varied among cycles. Time-normalization was applied to allow comparison of cycles. The cycle time within each cycle was divided into 100 equally wide time bins and joint angles were approximated with interpolation at the beginning of the bins. Similarly, EMG amplitudes of each individual muscles were interpolated. Then joint angle and muscle activity variances were computed across cycles at each percentage of cycle time. The variances obtained in low, medium and high resistances were compared applying repeated ANOVA. Our results support significant effect of resistance on the variances of muscle activities. When cycling with two arms, it was found that for the left arm there is a significant difference in the muscle activity variances obtained in low and high resistance conditions. For the right arm, significant differences were found between low and high and also between low and medium resistance conditions. Higher resistance induced higher variances of muscle activity profiles.
When cycling only with the left arm, there were significant difference between low and medium and also between low and high RCs and the difference was marginally significant between data obtained

in medium and high RCs. In contrast, when cycling only with the right arm, resistance condition did not affect muscle activity variances.
Variances of joint angles did not differ significantly for the three resistance conditions, neither in bimanual nor in unimanual cycling.
The main conclusion is that the movement is stabilized at kinematic level (joint angles). To keep this stability when cycling against higher resistance the muscles use more variable muscle activity patterns. The movement is controlled through stabilizing arm configurations and less by stabilizing muscle activity patterns. The exception is when cycling is performed only by the right arm, the reason of this may be that the central control of the dominant arm is so robust that even muscle activity patterns are stabilized and their variance is not effected by external resistances. Although the left arm's less stable performance is transferred to the right arm's movement when cycling bimanually against higher resistances.