

ELECTROMYOGRAPHIC CORRELATES OF INTERNAL MODELS OF TARGET REACHING TASKS IN RANDOMIZED FORCE FIELDS

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INTRODUCTION

It is believed that our ability to perform motor tasks in diverse environments expertly emerges from our capacity to store internal models of tasks, tools and environments in our memory.¹⁻²

Electromyography (EMG) has been shown to provide physiological correlates of such internal models since motor adaptation to a new dynamic environment would require changes in the activation patterns of the involved muscles.³

Healthy human subjects have been shown to be capable of learning a motor task in a randomly changing dynamic environment.⁴ We believed that such an adaptation would stem from discrete changes in the activation patterns of the principle muscles involved in this task. Based on a past study that showed distinct EMG changes during early and late phases of learning a motor task³, we hypothesized that learning a motor task in a randomly changing dynamic environment subjects would not only involve reduction of the EMG onset time and the EMG integrated activity of the prime mover but also demonstrate a shift in the directional bias of EMG spatial activity.

METHODS

Nine neurologically healthy right-handed subjects (27.67 ± 4.27 years) made 15cm center out target reaching movements with the dominant hand in a randomized dynamic

environment while being seated on a chair. This was performed while holding the manipulandum of a two-joint robotic arm. The start, target and instantaneous hand positions were displayed to the subject on a computer monitor kept in front of the subject. Subjects performed 2 blocks of practice trials and 1 block of baseline trials without the force field being applied. The force field was applied in 5 blocks of reaching trials for a total of 200 movements. The randomized dynamic environment was created using velocity dependent viscous curl fields which was always orthogonal to the hand velocity and formed a counterclockwise circulating pattern. The amplitude of the perturbing force varied randomly from one trial to the next. EMG of the biceps brachii, long head of triceps and the anterior & posterior deltoid muscles were recorded. Repeated measures ANOVA was used to find statistical significance for the following dependent variables – EMG onset and integrated EMG activity. The independent variables were muscle (4 levels), target direction (8 levels) and muscle action type (agonist or antagonist).

RESULTS AND DISCUSSION

Late training had significantly earlier onset of EMG activity than baseline or early training trials ($p < 0.005$). This is shown in figure 1 for one subject. This finding had been demonstrated in the past in non-randomized dynamic environments.^{3,5}

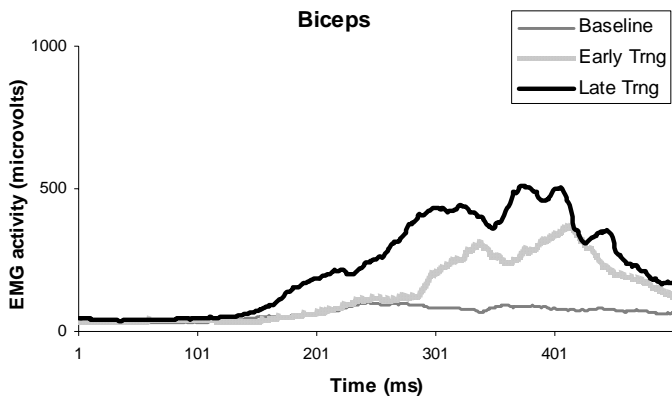


Figure 1. The EMG time series of the biceps muscle in one subject in baseline, early and late training during performance of the reaching movement in the 315° target (from the positive x-axis).

There was a significant reduction in integrated EMG activity after training ($p < 0.05$). Past literature has shown that dynamic tasks require finer control than increased co-contraction and end point stiffness.^{3,6} The direction of optimal activity for muscles involved in dynamic tasks demonstrates rotation with motor learning.^{3,5} In presence of unpredictable dynamic environments, the directional bias of the muscles show reversal of rotation ($p = 0.012$) between baseline to early and early to late training (figure 2).

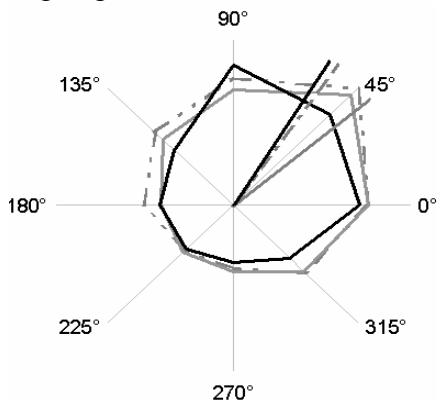


Figure 2. The directional effect of the integrated EMG activity as a polar plot for

the anterior deltoid muscle. Resultant vectors of the integrated EMG activity in the 8 directions are shown by dashed and dotted grey lines for baseline, solid grey lines for early training and solid black lines for late training.

SUMMARY/CONCLUSIONS

Electromyographic correlates of motor adaptation in an unstable dynamic environment were shown. These include an earlier onset of EMG and a significantly reduced integrated EMG activity with training. An initial rotation of the EMG bias during early training reversed and rotated back to the baseline in late training. Future studies involving electrophysiological and neurophysiological data from the higher centers of the central nervous system may provide a clearer picture of internal models in randomized force fields.

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