IMPEDANCE MODULATION WITH PRECISION DEMANDS IN DISCRETE MOVEMENTS

Luc P.J. Selen, Peter J. Beek and Jaap H. van Dieën
Institute for Fundamental and Clinical Human Movement Sciences, IFKB, Vrije Universiteit, van der Boechorststraat 9, 1081 BT Amsterdam, The Netherlands; email:Luc.Selen@fbw.vu.nl

INTRODUCTION

Human motor performance is intrinsically variable, but this variability is tuneable, as evidenced by the speed-accuracy trade-off. Recently, impedance modulation has been suggested as a means to decrease motor output variability [1,2]. Unlike previous studies, in which impedance was estimated from muscular (co)-activation, we conducted an experiment in which we estimated the impedance from mechanical perturbations.

METHODS

Twelve subjects participated in the experiment. Their right forearm was cast (NobaCast) to a splint, which was attached to a torque controlled motor. Two targets were presented on a ledbow placed 1.5m in front of the subject. A laserpointer attached to the splint indicated the pointing direction of the arm on the ledbow. Three different targets (3, 6 and 9cm in width) were presented in blocks. Subjects were instructed to make discrete, 35^{o}, target-to-target flexion movements, with a movement time between 270 and 330ms. After each trial, the performance was fed back to the subject. Each blok consisted of 165 flexion movements of which 20 were perturbed by a torque pulse of 5Nm and a duration of 70 ms duration.

For the unperturbed trials that matched the time and precision constraints we determined the trajectory variability. The perturbed trials were matched to the best fitting unperturbed trial [3] to find the trajectory deviation after perturbation. These trajectories were normalized to the maximum deviation in all trials of each subject individually. The maximum deviation was used as a first order estimate of the impedance. ANOVAs for repeated measures were performed on both the trajectory variability and the impedance changes.

RESULTS AND DISCUSSION

Figure 1 shows the standard deviation over all correct unperturbed trials for the different targets for all subjects. Trials were aligned to movement onset. Notice the decrease in variability when entering the target region (300-400ms) and the subsequent increase. This monotonic behavior was present in the correct trials of all subjects. Figure 2 shows the normalized maximum trajectory deviation after perturbation. Although overall the deviation increases with target width, the large standard deviations reflect that impedance modulation is not present in all subjects.

So far, only the maximum trajectory deviation was analyzed as an impedance estimate. In future work we will try to explicitly model the elbow joint as a second order system, resulting in quantitative measures of stiffness and damping.

CONCLUSIONS

This study shows that impedance modulation and precision demands go hand in hand. Whether this impedance modulation is a strategy for reducing motor output variability in the face of precision constraints remains unclear. Osu et al. [1] presented a similar result, based on EMG activity. Although group averages indicate that impedance is modulated with precision demands, in single subjects this is not always the case. Apparently, other strategies to meet precision demands are available, even in single degree of freedom, time-constrained movements.

REFERENCES

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3. Popescu F., et al. Exp Brain Res 152, 17-28, 2003

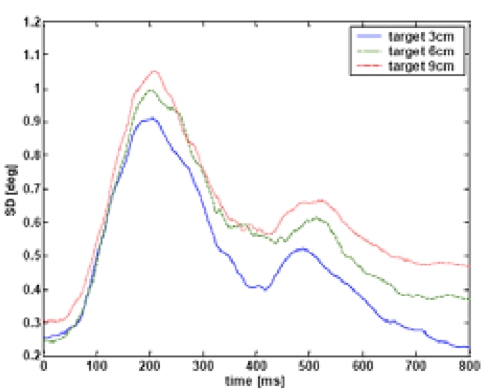

Figure 1: Kinematic variability over all subjects in the correct trials. The variability of the 3 cm target is different from the 6cm and 9cm target after 300ms

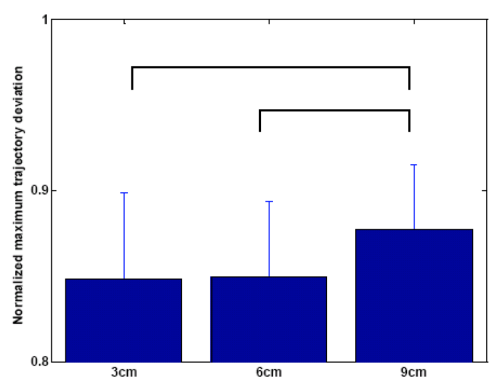

Figure 2: Impedance estimate (expressed as the normalized maximum trajectory deviation) for all subjects . The 9 cm target is significantly different from the 3cm and 6 cm target.