PREPARATION TO A PREDICTABLE PERTURBATION DURING MULTI-FINGER FORCE PRODUCTION

Sun Wook Kim, Jae Kun Shim, Vladimir Zatsiorsky, and Mark Latash
Department of Kinesiology, The Pennsylvania State University, University Park, PA 16802
email: mll11@psu.edu

INTRODUCTION

Two recent studies (Shim et al. 2005, Olafsdottir et al. 2005) have described changes in covariation patterns among finger forces involved in a multi-finger force production task in preparation to a change in the total force. This novel phenomenon has been termed anticipatory covariation (ACV). During steady-state total force production, individual finger forces typically show negative covariation both along a trial and across trials. This negative covariation stabilizes the total force, i.e. resists its deviations from the steady-state level. ACV has been assumed to facilitate planned changes in the total force by decreasing the negative covariation.

We investigated patterns of finger force covariation in experiments with force perturbations applied during the task of four-finger total force production at a comfortable constant level. The perturbations were triggered either unexpectedly or by the subject himself/herself. We hypothesized that ACV would be observed prior to the moment of force perturbation in trials with self-triggered perturbations but not in trials with perturbations triggered by the experimenter unexpectedly.

METHODS

Twelve healthy, right-handed volunteers, six males and six females participated in the experiment. The subjects sat comfortably in a chair and positioned the right forearm on the horizontal board directly in front of the subject. The fingertips of the right hand were placed on unidirectional force sensors spaced to fit the subject's individual anatomy. Changes in the forearm and hand position were prevented by a set of Velcro straps and using a custom-fitted wooden piece placed under the palm. A loop was placed on each finger and positioned under the distal interphalangeal joint. Each loop was connected to a 0.3 N load through a pulley system and an electromagnetic lock. The loads created forces acting on the fingers upwards. The subjects watched a 17" monitor that showed a target force level and the actual total force measured by the four sensors.

The subjects were required to press naturally on the sensors and to match the total force as accurately as possible with the target level. The target force was set at 8 N. There were four series (12 consecutive trials each) presented in a balanced order. Each trial lasted 10 s and involved unloading of one of the fingers disengaging the lock at some time over the second half of the trial. After the unloading, the subjects were required to bring the total force back to the required level as quickly as possible. Two series involved unloading of the index finger (I), either unexpectedly by the experimenter (I-Exp) or by the subject (I-Self); two other series involved unloading of the ring finger (R-Exp and R-Self).

All trials within a series were aligned by the time of unloading (t_0). Average time profiles of the total force and individual finger forces were computed for each series and each subject separately. Further, variance of the total force (V_{TOT}) and the sum of the variances of individual finger forces ($\sum V_{Fi}$) were computed and used to compute an index of finger force covariation, $\Delta V = (\sum V_{Fi} - V_{TOT})/\sum V_{Fi}$. The time of ΔV changes associated with the unloading was defined when it deviated from its average level over the steady-state force production by over 2 standard deviations.

RESULTS

No changes in the total force level were observed prior to the unloading in all series. An unloading was accompanied by an increase in the force produced by the unloaded finger on its sensor followed by corrections of all finger force. During steady-state force production, ΔV was about 0.75 in all series corresponding to negative covariation of finger forces. In I-Exp and R-Exp series, a drop in ΔV was observed on average about 25 ms after t_0. In contrast, during I-Self and R-Self series, these changes started, on average more than 100 ms prior to t_0. Following a perturbation, ΔV dropped dramatically and reached, on average -0.20 for I-Exp and R-Exp series and -0.10 for I-Self and R-Self series.

DISCUSSION AND CONCLUSIONS

Our observations support the hypothesis that humans can change patterns of finger force covariation in anticipation of a planned change in the total force. These observations extend results of the earlier studies (Shim et al. 2005, Olafsdottir et al. 2005) to ACV in preparation to a quick correction of the total force following a self-triggered perturbation. In that sense, the phenomenon of ACV is somewhat similar to the anticipatory postural adjustments. Apparently, ACV allowed subjects to avoid excessive total force destabilization over the period of correction as reflected in less negative ΔV values in I-Self and R-Self series.

REFERENCES

1. Shim JK, Olafsdottir H, Zatsiorsky VM, Latash ML (2005) The emergence and disappearance of multi-digit synergies during force production tasks. Exp Brain Res (in press)
2. Olafsdottir H., Yoshida N., Zatsiorsky V.M., Latash M.L. (2005) Anticipatory covariation of finger forces during self-paced and reaction time force production. Neurosci Lett (in press).

ACKNOWLEDGEMENTS

This research was supported in part by NIH grants AG-018751, NS-035032, and AR-048563.