EFFECT OF VISUAL UNCERTAINTY ON ADAPTATION TO ANKLE PERTURBATIONS

Timothy N. Judkins[1,3], Lewis A. Wheaton[1,3], J.C. Mizelle[1], Hermano I. Krebs[2,4,5], Richard F. Macko[2,3], and Larry W. Forrester[1,2,3]
[1]Deptartments of Physical Therapy and Rehabilitation Science and [2]Neurology, University of Maryland School of Medicine. Baltimore, MD
[3]Baltimore VA Medical Center and GRECC, Baltimore, MD
[4]Mechanical Engineering Department, Massachusetts Institute of Technology, Cambridge, MA
[5]Department of Neurology and Neuroscience, Weill Medical College of Cornell
Email: tjudkins@som.umaryland.edu, web: http://pt.umaryland.edu

INTRODUCTION

The human nervous system is capable of adapting to a wide variety of environmental perturbations such walking over ice or rough terrain. In the case of reaching, the brain adapts to these unknown dynamics by making adjustments to motor commands to achieve desired hand or tool position [1]. It has been shown that errors made while perturbed in a velocity-dependent conservative force field are well predicted using memory of the previous movement error as well as estimates of current and previous perturbations [2, 3]. This short-term motor adaptation occurs during reaching in many environments, but has remained virtually unexplored in the lower extremity. The objective of this study is to determine how visual feedback affects sensorimotor integration during simple ankle movements in randomly perturbed force fields

METHODS

Following Institutional Review Board requirements, informed consent was obtained from seven healthy volunteers who had no known history of neurological events, no significant visual problems and were able to move the ankle freely through a range of variable stiffness settings. For testing, subjects were seated with a two degree-of-freedom ankle robot (Anklebot; Interactive Motion Technologies, Cambridge, MA) attached to their left leg. A table blocked direct view of the subject's legs at all times, and a cursor representing the subject's ankle position was displayed on an LCD (Figure 1). Ankle and cursor position data were collected at 200 Hz.

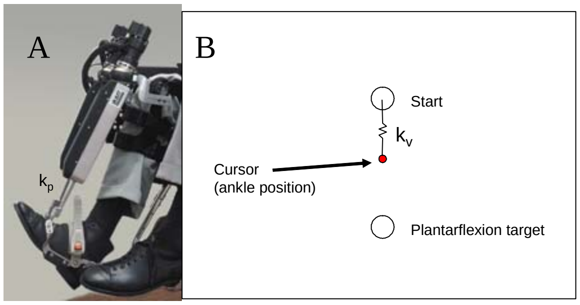

Figure 1: A) The anklebot produces a spring-like load (k_p). B) A virtual spring (k_v) is applied to the cursor. Subjects were instructed to make "down-and-up" movements to a plantarflexion target in 0.5 seconds.

Subjects performed "down-and-up" ankle movements in the sagittal plane against a spring-like load generated by the Anklebot. The subject was instructed to plantarflex to a target (-3.5°) and return to the start location (3.5°) in 0.5 sec. The stiffness of the robot varied randomly from trial-to-trial. Three visual feedback conditions were studied: veridical vision and proprioception (**V=P**), no vision (**PO**), and stochastic vision (**V≠P**). During **PO**, the cursor was not displayed. During **V≠P**, a randomly varying, virtual stiffness was applied to the cursor. Movement extent errors were modeled using an autoregressive model:

$$\varepsilon_p^{\,i} = \beta_0 k_p^{\,i} + \alpha_1 \varepsilon_p^{\,i\text{-}1} + \beta_1 k_p^{\,i\text{-}1} + \gamma_0 \varepsilon_v^{\,i} + \delta_0 k_v^{\,i} + \gamma_1 \varepsilon_v^{\,i\text{-}1} + \delta_1 k_v^{\,i\text{-}1} \qquad [1]$$

where $\varepsilon_p^{\,i}$ is current trial proprioceptive movement error, $\varepsilon_p^{\,i\text{-}1}$ is previous trial proprioceptive error, $\varepsilon_v^{\,i}$ is current trial visual error, $\varepsilon_v^{\,i\text{-}1}$ is previous trial visual error, $k_p^{\,i}$ is current trial physical stiffness, $k_p^{\,i\text{-}1}$ is previous trial physical stiffness, $k_v^{\,i}$ is current trial virtual stiffness, and $k_v^{\,i\text{-}1}$ is previous trial virtual stiffness. A one-way Analysis of Variance (ANOVA) was used to compare the standardized coefficients of the model across conditions for all subjects.

RESULTS AND DISCUSSION

As expected, current trial perturbation strength had the most influence over movement errors, and there were no significant differences between conditions (Figure 2). Subjects relied on prior proprioceptive errors the most when only proprioception information was available (**PO**), and the least when there was conflicting visual information (**V≠P**). Subjects relied on prior perturbation strength more in the **PO** and **V=P** conditions compared to **V≠P**. These results suggest that there is context-dependent weighting of sensory information depending upon the availability and consistency of the information.

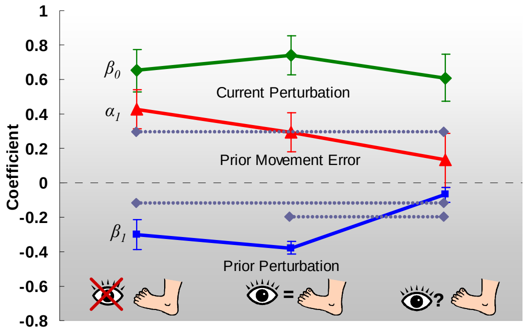

Figure 2: Standardized coefficients for each term in the short-term adaptation equation (Eq. 1). Horizontal bars indicate p<0.05 between conditions.

SUMMARY/CONCLUSIONS

This study clearly demonstrated that the availability and consistency of visual information modulates sensory weighting for motor adaptation at the ankle. However, it remains unclear how ankle motor adaptation may be affected by sensorimotor deficits. Future studies will investigate sensorimotor integration for ankle motor control in neurologically impaired populations such as stroke and peripheral neuropathy.

REFERENCES

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