

Effect of Weight and Number of Fingers on Bimanual Force Recreation

Benjamin Rigsby¹ and Kyle B. Reed¹

Abstract—This work focuses on bimanual force perception by assessing the affect of the number of fingers used to sense and recreate forces and the affect of the magnitude of the force applied. We found statistically significant effects from varying the number of fingers and a relationship between applied load and accuracy. Additionally, our results agree with previous studies that show there is a natural tendency to overestimate self-generated forces.

I. INTRODUCTION

Humans have the ability to use tools very efficiently and an unprecedented ability to share knowledge. However, in many cases we are limited by our own inefficiencies. One of these inefficiencies is force perception. Several studies have shown that self-generated forces are attenuated, which leaves a gap between what we think we are doing and what we are actually doing. This attenuation results in a significant increased force when a subject is asked to recreate a given force. The recreated force is consistently larger than the actual force applied to the participants [1][2].

This experiment investigates whether the body’s ability to control the force output of individual fingers separately could affect a subject’s accuracy during a force perception task. The ability to control individual force production control has been demonstrated previously [3][4]. Similarly, the affect of a weight’s magnitude on recreation accuracy has been partially shown by Prasad et al. [5].

II. METHODS

Two levers were presented with a 1D force sensor at the end of each lever. The participant was asked to press down on the lever with weights to lift up the weights (unseen by the participant) and then to recreate the force with the other hand on an unmoving lever for five seconds. Participants were told by the administrator to use either one finger (index finger) or three fingers (index, middle, and ring fingers). Five different weights were randomly applied to one or three fingers with four repetitions (40 total trials).

All the participants were male. Half were right hand dominant and half were left. This study was approved by the University of South Florida’s Institutional Review Board and all participants signed an approved consent form.

III. RESULTS & DISCUSSION

A three-way repeated measures ANOVA was performed with relative error between the hands as the dependent variable and independent variables were the number of fingers (one or three), weight applied (4N, 6.4N, 8.8N,

11.3N, 13.7N), and learning effects (over four repetitions). As expected, learning was not statistically significant. Number of fingers was statistically significant ($F(1, 9) = 14.89$, $p = .004$) with force recreation error means of 26% and 47% for one and three fingers, respectively. The amount of weight was statistically significant ($F(4, 36) = 9.02$, $p < .01$).

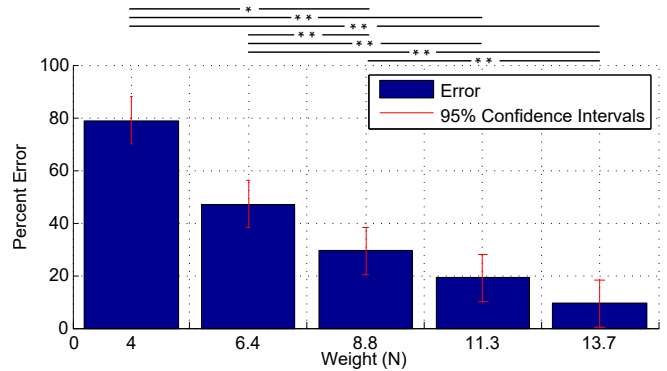


Fig. 1. The post-hoc test with Bonferroni corrections is shown here for accuracy vs weight. Note: * means $p < .05$ and ** means $p < .01$

Our results reaffirmed the findings of previous research showing that humans have a tendency to overestimate self generated forces. Additionally, using one finger was more accurate than three fingers with 45% less error. Both of these results, in combination with a participant survey, confirmed the disconnect between intended and actual actions. Interestingly, although our weights followed a linear distribution, the weight-accuracy relationship seen in Figure 1 follows an exponential function with weight inversely affecting error. We want to verify and expand on this relationship by testing more finger combinations on a system that dedicates a force sensor for each finger and by using a larger range of weights. All our results show both fingers and weight factors affected bimanual force recreation.

REFERENCES

- [1] S. S. Shergill, P. M. Bays, C. D. Frith, and D. M. Wolpert, “Two eyes for an eye: the neuroscience of force escalation,” *Science*, vol. 301, no. 5630, pp. 187–187, 2003.
- [2] N. L. Valles and K. B. Reed, “To know your own strength: overriding natural force attenuation,” *Haptics, IEEE Transactions on*, vol. 7, no. 2, pp. 264–269, 2014.
- [3] B. B. Edin, G. Westling, and R. S. Johansson, “Independent control of human finger-tip forces at individual digits during precision lifting.” *The Journal of physiology*, vol. 450, p. 547, 1992.
- [4] Z.-M. Li, M. Latash, and V. Zatsiorsky, “Force sharing among fingers as a model of the redundancy problem,” *Experimental brain research*, vol. 119, no. 3, pp. 276–286, 1998.
- [5] M. R. Prasad, M. Manivannan, and S. Chandramohan, “Effects of laparoscopic instrument and finger on force perception: a first step towards laparoscopic force-skills training,” *Surgical endoscopy*, vol. 29, no. 7, pp. 1927–1943, 2015.

¹Authors are with the Department of Mechanical Engineering, University of South Florida, Tampa, USA kylereed@usf.edu
This research is supported by the NSF under Grant Number IIS-1319802.