FINGER ENSLAVING IN THE DOMINANT AND NON-DOMINANT HAND

[1]Luke A. Wilhelm, [2]Joel R. Martin, [1]Mark L. Latash, and [1]Vladimir M Zatsiorsky

[1]The Pennsylvania State University, University Park, PA, USA
[2] George Mason University, Manassas, VA
Email: law326@psu.edu

INTRODUCTION

Patterns of finger force production and finger coordination have been well documented. Force production patterns in multi-finger maximum voluntary contraction (MVC) tasks have been modeled with a neural network [1]. In particular, finger enslaving, the unintentional force production by non-task related fingers, has been consistently observed. Enslaving has been suggested as an indirect measure of dexterity, since lower enslaving would imply a greater ability to move the fingers independently. In addition, the dynamic-dominance theory states that the dominant (D) arm and hand are better suited for dynamic tasks, while the non-dominant (ND) arm and hand are better suited for stabilization tasks [2]. The purpose of this study was to compare enslaving values between the D and ND hands using the neural network approach. Previous work suggested that there are significant, though small, differences in enslaving between the hands [3]. Given the background of the dynamic-dominance theory, we hypothesized that the enslaving effects would be lower in the D hand.

METHODS

Twenty-two right-handed, young, healthy males were tested. Handedness was assessed by the Edinburgh Handedness Inventory, the Grooved Pegboard test, and the Jebsen-Taylor hand function test.

The MVC task was performed by 15 different finger combinations (I, M, R, L, IM, IR, IL, MR, ML, RL, IMR, IML, IRL, MRL, IMRL, where I designates the index finger, M – the middle finger, R – the ring finger, and L – the little finger). Subjects were instructed to produce maximal force with the fingers of a given combination and to pay no attention to the non-instructed fingers.

Neural network analysis resulted in the following equation:

$$[F] = \frac{1}{N}[w][X] + [v][X] \tag{1}$$

where [**F**] is a 4×1 matrix of individual finger forces, N is the number of fingers explicitly involved in the given task, [**w**] is a 4×4 finger connection weight matrix, [**X**] is a 4×1 matrix of neural command values ranging from zero (finger not explicitly involved) to one (finger maximally involved), and [**v**] is a 4×4 diagonal matrix of gain values. For the case when all four fingers are explicitly instructed to press, the equation can be reduced to:

$$[F] = [IFC][X] \tag{2}$$

where [**IFC**] is referred to as the interfinger connection matrix. The diagonal elements of the IFC represent the amount of force produced by the fingers due to direct commands, and the off-diagonal elements represent the amount of force produced due to enslaving effects. The elements of the IFC were normalized by the total four finger force. The sum of normalized, off-diagonal elements was taken to be the enslaving index for a given subject. Enslaving indices for each individual finger were calculated by summing the off-diagonal elements in the appropriate column of the IFC (first column for the index finger, second column for the middle finger, third column for the ring finger, and fourth column for the little finger).

RESULTS AND DISCUSSION

The results of a two-way ANOVA analysis (*hand × finger*) showed the index finger to have the lowest enslaving effects, while the ring finger showed the highest enslaving. This agrees with previous enslaving patterns found in the literature. However, no significant difference in enslaving indices was found between D and ND hands (Fig. 1).

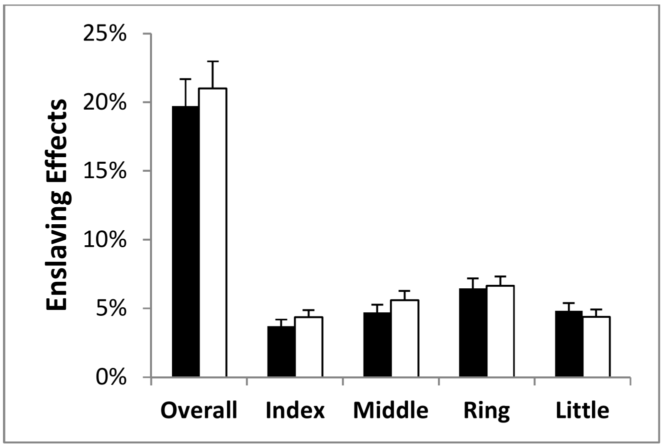

Figure 1: Percent of total force produced during the four finger task due to enslaving effects. Black bars are the D hand, and white bars are the ND hand.

The handedness scores from the Edinburgh Handedness Inventory, the Grooved Pegboard test, and the Jebsen-Taylor hand function test were compared with the enslaving indices with Pearson's *r*. All three tests showed greater hand function in the D hand. However, no significant correlations were found between any of the handedness tests and the enslaving indices.

Some previous work suggested that there are significant differences in enslaving effects between the D and ND hand. However, the reported differences were small, on the order of 2% [3]. In addition, these differences were only found in certain combinations of fingers, not all four fingers acting together. This, in combination with the current findings, suggests that any differences in enslaving effects between the hands are small.

Earlier studies have shown that although enslaving effects are a consequence of both peripheral mechanical coupling and central nervous system command coupling, neural factors play the largest role [4]. Furthermore, given appropriate practice and feedback, enslaving patterns have been shown to change, often in training sessions of no longer than one hour, suggesting that the neural mechanisms controlling enslaving are malleable [5]. Even though the D and ND hands are used differently in everyday tasks, the majority of tasks for both hands require multiple finger coordination as opposed to individual finger movement (e.g. grasping, object manipulation). We hypothesize that this prevalence of multi-finger tasks for both hands leads to similar patterns of enslaving in the D and ND hands.

CONCLUSIONS

Enslaving effects were not found to differ between D and ND hands when using the neural network method of analysis. We hypothesize that, although the D hand shows greater dexterity in functional tests, everyday use does not require extensive finger individuation. This creates similar patterns of enslaving between the D and ND hands.

REFERENCES

1. Zatsiorsky VM, et al. *Biol. Cybern* **79**, 139-150, 1998.
2. Sainburg R, *Exp Brain Res* **142**, 241-258, 2002.
3. Li S, *Human Move. Sci* **19**, 897-923, 2000
4. Latash ML, et al. *Brain Res* **924**, 198-208, 2002
5. Wu Y, et al. *J of Motor Behavior* **44**, 471-478, 2012

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