ENSLAVING EFFECTS OF FINGER MOVEMENT ON PRESSING FORCES OF OTHER FINGERS

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INTRODUCTION

Studies of finger kinetic and kinematic interactions have shown that fingers are interdependent each other (for a review see Schieber and Santello 2004). Kinetic and kinematic enslaving effects are larger in neighboring fingers (e.g. in the index finger-middle finger or middle finger-ring finger pairs) then in the fingers positioned farther from each other (e.g. in the index finger-ring finger pair). These effects were studied both in static force production tasks (Zatsiorsky et al. 1998) and during finger movements (Hager-Ross et al. 2000; Li et al. 2004). However, interdependence between the static force production and finger movement has not been addressed. The purpose of the current study was to investigate the effects of finger movement on the finger-tip forces of other fingers. We hypothesized that the effects depend on the fingers proximity and are the larger the closer the fingers to each other (proximity hypothesis).

METHODS

Equipment: One goniometer (Sensor SG65 Biometrics Ltd.) and six piezoelectric sensors (Model 208C02, Piezotronic, Inc.) were used (Figure 1) to record metacarpophalangeal (MCP) joint angles of a finger in motion (task finger) and finger-tip forces of the rest of fingers (non-task fingers). The sensors were horizontally movable on an aluminum panel, and they were fixed according to hand anatomy of individual subjects. The hand position was maintained constant, but the aluminum panel was vertically moved so that a task finger could move through the slot.

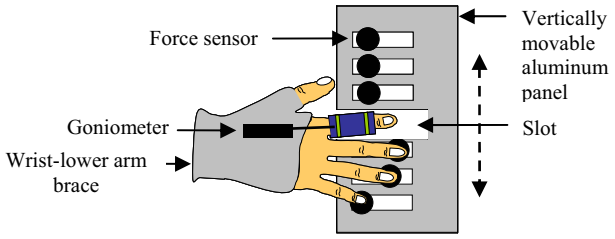

Figure 1. Experimental setup.

Experimental Procedure: Ten healthy, right-handed volunteers, five males and five females participated in the experiment. Subjects sat on a chair with their right lower arms positioned on a table and strapped with a set of Velcros. A wrist-forearm brace (EBONITE Inc.) was used to immobilize the wrist. A small aluminum bar was used to restrict the movement of proximal and distal interphalangeal joints of a task finger. Before each trial, subjects extended all phalangeal joint angles into approximately 180° with the thumb pointing upward. Subjects flexed the MCP joint of one finger each time to its maximum range of motion through a hole at a comfortable speed, and isometric pressing forces on finger-tips of non-task fingers were recorded. Non-task finger forces at the time of the maximum range of motion of a task finger were extracted to quantify enslaving forces of non-task fingers.

RESULTS

Neighboring fingers of a task finger produced approximately 67% of the total force, and non-neighboring fingers generated about 33%. In the tasks with two neighboring fingers (e.g. middle and ring finger tasks), index and middle fingers showed larger enslaving forces than the other neighboring fingers. During index and little finger tasks, the enslaving force magnitudes decreased with distance to the task fingers (i.e. index finger enslaving force was the smallest during the little finger task).

CONCLUSIONS

Our observations support the proximity hypothesis; fingers positioned closer to a task finger produce larger enslaving forces. These observations extend results of the earlier studies of kinetic and kinematic enslaving (Zatsiorksy et al. 1998; Hager-Ross et al. 2000; Li et al. 2004) to enslaving of non-task finger forces in response to a kinematic movement of a task finger.

REFERENCES

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Table 1: Finger-tip pressing force responses in non-task fingers to a maximum MCP joint flexion of a task finger (Mean ± S.D.)

Task fingers	Non-task finger force responses (% sum of all finger forces)			
	Index	Middle	Ring	Little
Index	-	59.51 ± 5.24	25.22 ± 3.92	15.27 ± 3.18
Middle	52.92 ± 7.22	-	35.03 ± 4.56	12.05 ± 2.12
Ring	16.32 ± 3.49	59.99 ± 5.00	-	23.69 ± 4.01
Little	18.38 ± 4.00	24.84 ± 4.93	56.78 ± 6.46	-