Effect of Contralateral Condition during Bimanual Pinch Force Control

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Keywords: Bimanual, Pinch, Fine Motor Control.

Abstract: The purpose of this study is to investigate the effect of the interaction of different control of the opposite side during bimanual finger pinch force output. Thirty two young adults (20.5±2.0y) participated in this study. Participants were requested to control their pinch forces at 10%MVF with visual feedback. Participants were asked to turn off their force output to zero (0%MVF) if visual feedback disappeared, and maintain their force output at 10%MVF when it's appeared. There are 4 different force producing types: increase force output from 0 to 10%MVF (UP), decrease force output from 10 to 0%MVF (DOWN), keep maintaining 10%MVF (KEEP) and waiting at 0%MVF force output level (WAIT). The error trial was defined as when UP side of the hands' force output exceeded 10.6%MVF. We calculated the error ratio as the number of error trials per total numbers of trial. The number of error ratio was the fewest on UP&UP, total 25/198 (Left: 17/96 Right: 8/96), followed by KEEP&UP total 52/192 (Left: 28/96, Right: 24/96) and WAIT&UP total 64/191 (Left: 40/96, Right: 24/95). Most mistakable condition was DOWN&UP, total 81/192 (Left: 50/96, Right: 31/96). The overshoot error ratio in right hand was lower than that of left hand.

1 INTRODUCTION

In our daily life, we often use both hands at the same time. During the bimanual movement, mirror-symmetric movements are tending to produced (Mechsner, 2001). In contrast, it is difficult to make asymmetric movements and interference can occur when two hands need to produce different forces or directions (Harabst, 2000); (Hazeltine, 2003). It can be said that control ability of one side limb is affected by the other during bimanual movement.

The purpose of this study is to investigate the effect of the interaction of different control of the opposite side during bimanual movement. We selected bimanual finger pinching as a task, because finger pinching was often used for fine motor control investigation.

2 METHODS

2.1 Participants

Thirty two young adults (20.5±2.0y) participated in this study. All participants were right-handed, evaluated by Edinburgh Handedness Inventory (Oldfield, 1971). The participants gave informed consent to the experimental procedures that had been approved by the Local Ethics Committee.

2.2 Procedures

Before performing the experimental task, each participant performed a series of finger-pinch maximal voluntary force (MVF). During the MVF measurement, participants were asked to press the load cells with thumb and index finger as strong as possible. The greatest value recorded in the two MVF trials for a particular hand was considered as the hand-specific MVF.

The experimental task was bimanual pinching with thumb and index finger. Participants were requested to control their pinch forces with visual feedback of hand's force production on the computer monitor. Visual feedback was given each hand separately. Target force was set at 10%MVF. Participants were asked to turn off their force output to zero (0%MVF) if visual feedback disappeared, and maintain their force output at 10%MVF when it's appeared. We instructed them to switch the control of their forces as quickly and accurately as possible. It consists of two switching points; preliminary 5 s maintain both hands finger pinch force output at 10%MVF, then disappearing or appearing the feedback at 5 s (first switching point) and remained till 10 s, then second switching point at 10 s after the beginning of the measurement. The task continues 15 s and participants didn't know the timing of switching point (Figure 1).

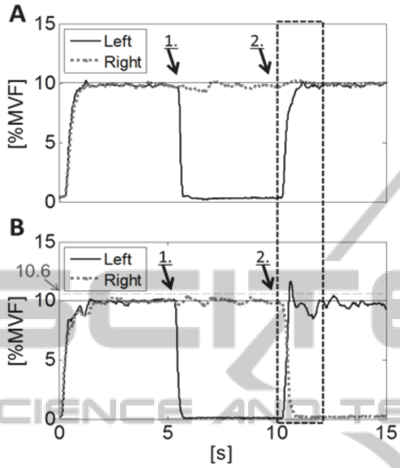

Figure 1: Representative force outputs for two conditions. A: Force output of LUP&RKEEP condition. B: Force output of LUP&RDOWN condition. 1 indicates first switching point (after 5seconds) and 2 indicates second switching point (after 10seconds). Rectangle with broken line indicates analyzing area. Left hand force output exceeded 10.6%MVF on B, became overshoot error trial.

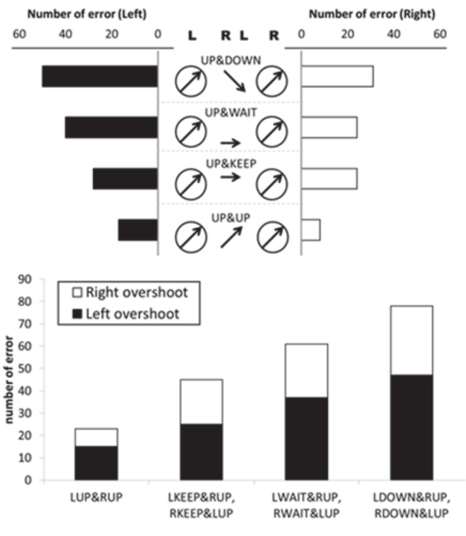

Figure 2: Number of overshoot error. Graph above shows a number of left and right overshoot error separately. Arrows inside the circle denote UP side while arrows in the middle of them indicate the opposite sides required force production (UP, DOWN, KEEP and WAIT). Graph below shows the total number of overshoot error.

2.3 Data Analysis

We focused on second switching point (Figure 1). There are 4 different force producing types: increase force output from 0 to 10%MVF (UP), decrease force output from 10 to 0%MVF (DOWN), keep maintaining 10%MVF (KEEP) and waiting at 0%MVF force output level (WAIT). Combination of them with both hands, there are 7 different conditions: LUP&RUP, LUP&RDOWN, RUP&LDOWN, LUP&RKEEP, RUP&LKEEP, LUP&RWAIT and RUP&LWAIT. Participants engaged three trials on each condition, arranged in random order. The error trial was defined as when UP side of the hands' force output exceeded 10.6%MVF before 2 s from second switching point. We calculated the error ratio as the number of error trials per total numbers of trial.

3 RESULTS

Error ratio of each condition was shown in Figure2. The number of error ratio was the fewest on UP&UP, total 25/198 (Left: 17/96 Right: 8/96), followed by KEEP&UP total 52/192 (Left: 28/96, Right: 24/96) and WAIT&UP total 64/191 (Left: 40/96, Right: 24/95). Most mistakable condition was DOWN&UP, total 81/192 (Left: 50/96, Right: 31/96). A chi-square test of independence was performed to examine the relationship between experimental tasks and overshoot error ratio. The relation between these variables was significant,$X^2(3, N = 767) = 42.3, p < 0.05$.

4 DISCUSSION

When controlling one side of limb's force output to certain target, overshoot error is influenced by the other side's force producing type. It is easy to control target force output when both hand's task are same force producing type. In contrast, it becomes difficult to control force output when anti-phase task is required on the other side. This may because the attention to the difficulty and complexity of the other side's limb movement and/or task disturbs the control of the force output.

The overshoot error ratio in right hand was lower than that of left hand. Certainly, the participants were all right-handed. Dominant limb is specialized for dynamic, feed-forward controlled unimanual tasks (Sainburg, 2002). There was relatively lower difference, however, between right and left error ration in UP&KEEP condition. In this condition, 10%MVF kept in one side seems to work as the reference point for the other side that raising force output from zero to 10%MVF. This reference was same on right and left hand and maybe made easy to increase force with feed-forward control.

The tasks used in this study were including with the cognitive reaction task since the participants were required to react as quickly and accurately as possible. In order to clarify the bimanual fine motor control, further studies are needed to expel the anticipation of required force output.

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