MECHANISMS OF PREPARATION FOR TASK SWITCHING IN A FINGER PRESSING TASK

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INTRODUCTION

Ensuring the stability of motor behavior is crucial for successfully performing steady-state movements. However, when transitions between movement types are expected, maximizing the stability of the current movement will hinder the execution of the transition [1]. We recently demonstrated that in a four-finger, isometric force production task, stability of the total force of the four fingers is reduced solely in response to a cue that creates an expectation of force change in the future [2]. The distribution of the demeaned finger forces obtained from multiple trials changed across a cue condition (shift from the black ellipse to the red ellipse; Fig. 1) that indicated variance reduction along the task-irrelevant directions in the space of finger forces. That is, the nature of the co-variation between the finger forces changed to suit the expected task of changing total force rather than the current goal of maintaining total force. This general preparatory strategy was demonstrated by all young, healthy subjects.

The purpose of this study is to identify if the mean force shifts in response to a cue (black ellipse to blue ellipse; Fig. 1). Such a change would support the notion that, in addition to the change in coordination, subjects restrict the finger forces to a specific set of configurations in the finger-force space that are better suited for rapid changes in the total force. This optimal subspace would depend on neuromechanical properties of the finger muscles, and would likely be subject-specific.

METHODS

Twenty-four healthy subjects (6 male, 20.4±2.5 yrs) participated in the study after providing informed consent. Subjects were seated comfortably in a chair with their forearms resting on top of a table. They placed the distal phalanx of each finger of their dominant hand on one force transducer (Nano-17; ATI Automation). The transducers recorded each finger's downward vertical force at 1000 Hz. Visual feedback on the total force, F_T, was provided via a computer screen placed in front of the subject. F_T was computed as the sum of the vertical downward forces of all fingers ($F_T=\sum F_i$; i=1 to 4).

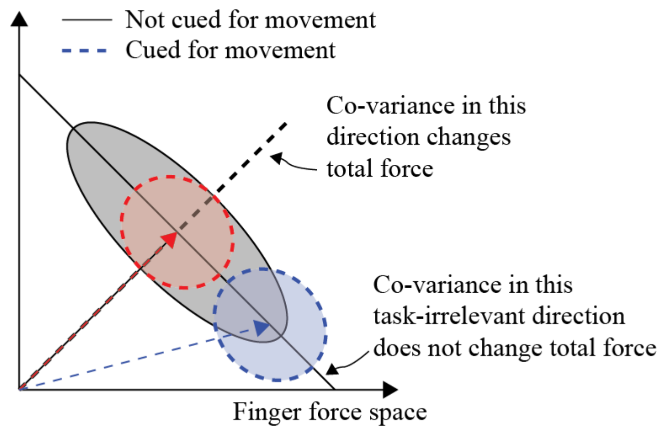

Figure 1: Distribution of demeaned finger forces changes in response to an expectation of movement (from the back to the red ellipse). Does the mean force also shift (black ellipse to blue ellipse)?

Subjects performed 16 trials in two experimental conditions. For the *steady* condition, subjects were instructed to produce a constant total force of 10% maximum voluntary contraction (MVC, measured earlier) for seven seconds. Finger forces from the last one second (6s – 7s) were isolated for analysis. For the *dexterous* condition, subjects tracked a variable target for 30 seconds. The force target moved unpredictably until at some point in every trial it stabilized at 10% MVC and remained there for at least 4 seconds, and then resumed its unpredictable movement. There were eight unique target traces for the dexterous condition, performed in a random order and repeated twice. The stationary portions of each dexterous trial were time-aligned to the first instant of constant force, and the mean of each finger force in the 3s – 4s window were computed. Note that the current task definition is identical in the analysis window in both conditions, but the subject expects upcoming movement only in the *dexterous* condition. For each subject, the finger forces from the 16 trials of the *steady* and *dexterous* tasks were subjected to paired-sample t-tests. Thus, 96 (4 fingers x 24 subjects) t-tests were conducted. We also computed the mean finger forces across the 16 repetitions for each task, and conducted four (one per finger) paired-sample t tests using data from all subjects.

RESULTS AND DISCUSSION

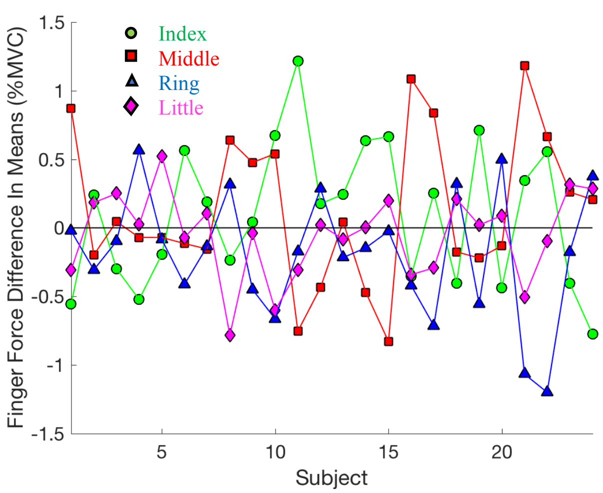

Figure 2: Difference in the mean finger forces for all subjects (n = 24). Means were computed across all trials of one task. Values shown are *steady* task mean force – *dexterous* task mean force for each finger.

Figure 2 shows the difference in the mean forces for all fingers and subjects. The error bars are omitted for clarity. The t tests for each subject consistently yielded differences in mean finger forces. Across conditions, 23/24 subjects significantly changed at least one finger force, 17/24 changed at least two, 8/24 changed at least 3, and 2/24 changed all finger forces ($p<0.05$).

Among only the significant changes in finger forces, the changes in the mean forces of the index and middle fingers ranged between 62% and 95% of their values for the *steady* task. More subjects decreased their index and middle finger forces (9/15 and 8/11, respectively). The change in force for the ring finger ranged between 26% and 89%, and for the little finger ranged between 4% and 81%. More subjects increased their ring finger force (9/15), and 5/9 subjects increased their little finger force.

In contrast to subject-specific comparisons, we did not observe significant changes in the mean finger forces between the two experimental conditions when data were pooled across subjects ($p>0.05$).

Based on these data, we claim that the expectation to change the total force produced by the four fingers prompts a change in the mean forces currently generated by the fingers to stabilize the current total force value. The change in mean is subject-specific. This is consistent with similar findings in adaptive locomotor studies: expectation to change the heading direction during forward locomotion leads to subject-specific changes in posture and gait patterns [3].

CONCLUSIONS

Preparation to transition between motor tasks consists of general and specific strategies. The general strategy is to change the coordination between input elements to suit the upcoming state transition. The specific strategy is to constrain the mean configuration of the input elements to an optimal subspace that is suited for the upcoming state change. In the present experiment, we hypothesize that the locations of these optimal subspaces depend on the impulse-production abilities of the individual fingers. This is a topic of our future research. Quantification of the mechanisms of motor preparation will facilitate the clinical evaluation of aberrant processes underlying deficits in motor transitions and assist in the development of rehabilitative strategies to address manual dexterity issues.

REFERENCES

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