

# TRANSFER OF DYNAMIC LEARNING ACROSS POSTURES

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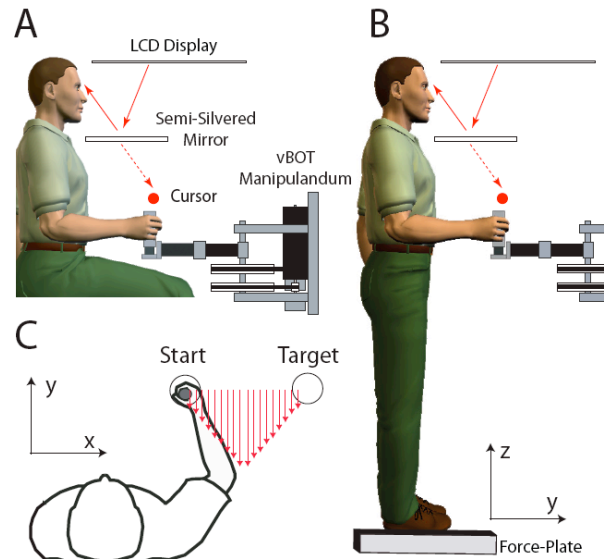
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## INTRODUCTION

Skilled movement depends upon our ability to control for external dynamics and predict the consequences of that control. Our everyday movements generate forces upon the environment, as well as forces upon our own bodies. When these forces are predictable, voluntary movement is usually preceded by anticipatory postural adjustments (APAs). When learning difficult motor tasks, we frequently decompose them so that the control of individual body segments is practiced in isolation. But upon re-composition, the movement will result in novel complex internal forces between the body segments that were not experienced (or did not need to be compensated for) during isolated practice. But can the postural system immediately predict and compensate for these dynamics? In this study we investigated whether the whole-body postural adaptations learned to compensate for movement dynamics in one posture, would transfer to a novel whole-body posture, when performing the same arm reaching movement.

To investigate these questions we used a well-established experimental paradigm for dynamic adaptation of reaching movements. Participants made reaching movements while grasping the handle of a robotic force-generating manipulandum, which generates a force perturbation proportional to the handle velocity, and perpendicular in direction. The gradual adaptation of a sensorimotor map for arm control consistently observed in previous studies, allowed us to quantify any adaptation of related anticipatory postural adjustments (APAs). APAs specific to the perturbation. Furthermore, we also analysed the learning of novel arm dynamics in different supporting postures, and the ability to transfer these representations between postures.



**Figure 1:** Experimental Setup; A: seated position; B: standing position; C: forces on FORCE trials.

## METHODS

Thirteen right-handed participants (7M/6F) made planar reaching movements while in seated and standing postures. Experimental procedures were approved by the Local Ethics Committee.

Participants grasped the handle of a force-generating robotic manipulandum (vBOT) and moved a cursor to a target presented in the horizontal plane. Task relevant visual feedback was presented within the plane of movement via a semi-silvered mirror, reflecting the display of an LCD monitor suspended horizontally above (Figure 1A). When standing, participants stood with feet slightly apart on a 6-axis force-torque sensor (ATI Technologies, Apex, NC) (Fig. 1B).

Participants were randomly assigned to either the STAND (N=7) or SIT (N=6) group, named for the postural configuration in which the first FORCE

trial was experienced. The STAND group initially performed 350 trials in the standing position. The first 50 were NULL trials, used to measure baseline performance (*Baseline*). The following 300 trials were FORCE trials (*Learning*). They then switched to a seated posture and performed 100 FORCE trials (*Transfer*), followed by 100 NULL trials to extinguish the adaptation (*Washout*). To quantify the transfer of the washout, participants then returned to the original standing configuration for another 100 NULL trials (*Transfer2*). In the SIT group, the order of postural configurations was reversed: 350 Sit trials; 200 Stand; 100 Sit. In FORCE trials, the robot generated a force upon the hand proportional to its velocity, and perpendicular (clockwise) to its direction, consistent with a viscous curl field (Fig. 1C). Catch trials were inserted randomly, (one in five trials) where a force channel was generated, restricting movement along a straight path directed towards the target by preventing motion in the perpendicular direction. Handle position, robot-generated forces, and forceplate forces were recorded at 500 Hz.

To assess learning of the dynamics in the seated condition we examined movement error on each trial, measured as the peak perpendicular deviation from the target vector (Fig 2A). To rule out the use

of an impedance-based strategy, we examined the peak force generated into the force channel on catch trials as a measure of anticipatory control (Fig 2B). Transfer of learning in the standing position was measured as the velocity of the center of pressure prior to the onset of movement. Movement of the center of pressure in the direction of the impending perturbing force would indicate an anticipatory postural adjustment (Fig 2C). Appropriate anticipatory control should lead to minimal reactive control, measured as COP velocity after movement initiation (Fig 2D).

## RESULTS AND DISCUSSION

Movement performance, quantified as movement error and peak catch force produced, transferred from sitting to standing (SIT group) and from standing to sitting (STAND group) (Fig 2A,B,  $p < 0.001$ ). Anticipatory postural adjustments specific to the arm perturbation gradually developed in the STAND group ( $p < 0.001$ , Fig 2C), and more slowly than the adaptation of movement control ( $p < 0.01$ ). APAs were immediately evident in the SIT group when they transferred to a standing position, even though they had not previously experienced the perturbation in that configuration (Fig 2C).

## CONCLUSIONS

Subjects' arm movements were exposed to a novel dynamic environment, which resulted in an adaptation of the sensorimotor map for arm movement, as well as the map for postural control. Additionally, the flexibility of APAs observed in well-practiced movements, is also observed in movements involving recently learned dynamics. Finally, the CNS can immediately anticipate the effect of novel dynamics on different body postures. These results support the existence of separate mappings for posture and movement, which encode similar dynamics but are adapted independently. This novel paradigm lends itself to the simultaneous investigation of the nature of the dynamic representations underlying posture and movement control in a variety of unfamiliar, yet well-controlled environments. A greater understanding of their adaptability and flexibility will provide essential insights to guide the development of future rehabilitation techniques and interventions.

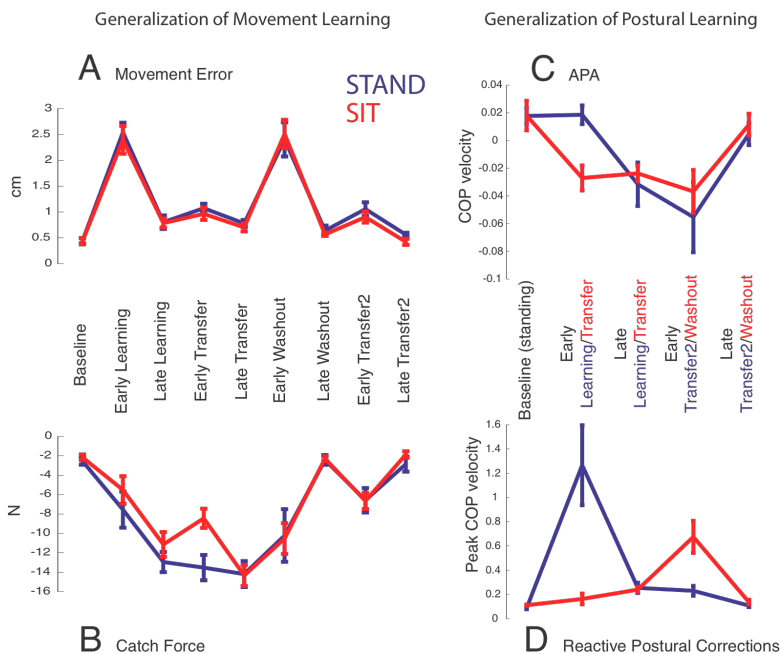


Figure 2: Results; A: Movement error; B: Anticipatory forces; C: Anticipatory postural adjustments; D: Reactive postural adjustments