# *Ocular Influence on Upper Limb Voluntary Movement*

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## Abstract

Most people in the world experience the world through their eyes and hands. As a species, we perform many tasks with our upper limbs while maintaining posture. However, very little is known about the visual system's role during upper limb voluntary movement after perturbations that require upper limb motor corrections and whole-body postural adjustments. Our study was designed to find the relationship between eye movements, center of pressure (COP), and muscle activation of the lower and upper limbs when a mechanical disturbance deviates a goal-directed reaching task. We hypothesized that neural copies of oculomotor signals, which track object-motion and are mediated by frontoparietal networks, serve as input to gate feedforward and feedback motor responses. With more testing we hope to better understand the relationship between hand and eye movements during upright stance. Our study could have implications for motor development and clinical rehabilitation in Parkinson's disease patients.

## Introduction

Many of the actions that we perform during the day throughout our lives involve standing and using our hands. For example, when we are playing catch with friends. As objects are in mid-flight, our motor and visual centers must work together to predict the correct trajectory for interception. However, sometimes we experience disturbances, such as a friend hitting our arm or, if we're playing in a ballpark, the wall brushing against us. This led us to wonder what's the relationship between eye movements, center of pressure (COP), and muscle activation during goal-directed reaching tasks while standing?

When we use our upper limbs voluntarily, our body activate mechanisms to stabilize our posture. One of the mechanisms that activate prior to voluntary movement to stabilize our posture is anticipatory postural adjustment (APA) (Cordo & Nashner, 1982). APA is a feedforward mechanism that occurs before the voluntary movement could potentially destabilize the body. It's designed to help keep our COP within a range to stop us from falling over from sudden postural changes. One of the ways it can be characterized is by the activation of the gastrocnemius about 100-150 ms before the biceps during a pulling or pushing task (Purves et al. 2018). A recent study found that when mechanical perturbations are applied to the upper limb, rapid activation of the lower limb muscles also occurs (Catherine et al. 2017).

One of the main findings was that lower limb responds either at the same time or after upper limb corrections during goal directed reaches. They also found significant changes in COP when performing the task in relation to the constant postural sway contributed by the soleus and gastrocnemius (Loram et al., 2005).

Our visual system plays a role in our movement planning and initiation. Eye movements are characterized into four forms: saccades, slow pursuit, and vergence (Purves et al., 2001). Our experiment is focusing primarily on smooth pursuit slow eye movements, to get a better understanding of the how the nervous system processes visual sensory information to stabilize the body when intercepting a moving target. An early study found that although not instructed to do so, subjects will use smooth-pursuit eye movements to track a target up to the time of interception for targets moving in quasi-unpredictable trajectories (Mrotek & Soechting, 2007).

Our study is designed to analyze the relationship eye movements have on center of pressure and muscle activation of the upper and lower limbs. To date, we do not completely understand the neural functions associated with catching moving objects and the role of the visual system in stabilizing posture. We hypothesized that neural copies of oculomotor signals, which track object-motion and are mediated by frontoparietal networks, serve as input to gate feedforward and feedback motor responses. Our hypothesis is based on the findings of a relationship between the adjustment of muscle activation and feedback gain to the relative speed of the body and a moving object (Gómez-Granados et al., 2021). Defining these functions would give us a better understanding of the complex integration of the sensory and motor systems within our brains. Examples in which a disconnect between these two systems include people that suffer from ataxia and some stroke patients. A symptom of ataxia is poor hand-eye coordination. By completing this experiment, scientific approaches to the neural aspect of movement will improve and there could also be clinical implications related to motor rehabilitation.

## Methods

### Participants

We will recruit ~10 subjects. We will collect written consent before they're allowed to participate in the experiment. They will also be screened for right-handedness, free of neurological disorders, muscular disorders, and ocular diseases. The protocol was approved by the Institutional Review Boards at The Pennsylvania State University. The duration of the experiment will be 1 day: 120 minutes. Participants will be compensated for their time.

### Experimental Apparatus and Setup

All tasks are performed on the KINARM end-point robotic device integrated with gaze-tracking and a single force plate sensor (BKIN Technologies, Kingston, ON, Canada). The KINARM robot will be adjusted vertically to allow each participant to stand comfortably and view the visual display that projected spatial targets and hand position (white circle, 0.5-cm diameter) onto the workspace. Participants will stand (only socks) on the single force plate sensor that measures ground reaction forces (GRFs) and moments in the medial/lateral (*x*), anterior/posterior (*y*), and vertical (*z*) axes. Subjects will be instructed to grasp onto the robotic handle comfortably while maintaining an upright posture and keep their weight equally distributed between their feet. During the entirety of the experiment the subject will observed to maintain their posture. Also, they will be harnessed to prevent falling in the instance loss of balance occurs.

## The Task

In the first condition, each trial starts with a yellow circular target appearing 20 cm from the midline. Participants are instructed to place the white dot representing their hand in the start target (target turns green). A fixation cross appears on the screen 10 cm from the start target. Participants are to look at the fixation cross. After a random delay, another target begins to move from the fixation cross at 30 cm/s towards the end target that appears 20 cm to the right of the fixation cross. Participants are instructed to intercept the moving target at the position of the end target. If the participants reach the end target within 150 ms before or after the moving target reaches the end target, it is considered a successful trail and the end target will turn green. However, if the participant reaches the end target before the 150 ms window, the end target becomes blue, and it is considered a failed trial. If the moving target makes it to the end target before the hand it is a failed trial. In ~20% of trials perturbations rapid perturbations (8 N) are applied when the hand had moved 3 cm and 9 cm (in the x-direction) from the start target. Perturbations will be applied orthogonal to the direction of the participant's hand movement.

In the second condition participants are instructed to intercept the moving target before it reaches the end target. If participants intercept the moving target before it reaches the end target it is considered a successful trial (end target turns red). If participants do not touch the target with their hand before it reaches the end target, the end target turns red, and the trial is unsuccessful.

Each condition will have 12 blocks consisting of 20 trials. Within each block there will be 4 perturbed (at 3 cm or 9 cm: towards or away). Trials will be presented in a random order for each block. To avoid fatigue participants will sit after every 4 blocks and rest for approximately 3 minutes.

## Muscle Recording

Our electromyographic (EMG) recordings will be taken from 12 muscles with surface electrodes. There will be 8 electrodes on the lower extremity and 4 on the upper extremity. The skin overlying the muscle will be cleaned with alcohol wipes, and electrodes will be placed on the muscle belly parallel to muscle fibers. Muscle activity will be collected from: anterior deltoid (flexion/medial rotation of shoulder), posterior deltoid (extension/lateral rotation of shoulder), triceps lateralis (elbow extensor), brachioradialis (elbow flexor). Muscle activity will be collected bilaterally from the lower limbs: tibialis anterior (ankle dorsiflexor), gastrocnemius medialis (ankle plantar flexor), rectus femoris (knee extensor), and long head biceps femoris (knee flexor). Muscle activity will be amplified, band-passed filtered (20-450 Hz), and digitally sampled at 1000 Hz.

## Discussion

Due to the time constraints of eight weeks, we were not able to collect data on participants. Therefore, we cannot make any conclusions based on the design of the experiment. However, the study is still ongoing and so far, we’ve completed one pilot where we collected EMG and COP data. We can speculate that participants would likely look at their hand after the perturbations to make the corrections. They may also focus on the target and try to use their peripheral vision and proprioception to make corrective movements. We hope to complete our research within the upcoming year.

## References

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