Design of a 3D Perspective Visual Illusion Paradigm to Study Intended and Spontaneous Motor Behavior

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Abstract

Our research is interested in understanding how visual feedback is utilized to affect our motor actions. It is unclear as to how the vision-for-perception (ventral) and vision-for-action (dorsal) pathways in the brain interact with one another to modulate motor control. By implementing a 3D visual illusion in our study, we are able to evoke bistable percepts, giving us an opportunity to segregate these pathways to determine their influences. Based on preliminary results, the illusory percept has a distinct effect on movement trajectories towards a target compared to the veridical condition. This implicates that the vision-for-perception pathway influences motor control.

Introduction

Over the last 20 years, the debate remains unclear as to how the vision-for-action and vision-for-perception pathways in the brain modulate motor behavior [1]. Past experiments did not look at full movement trajectories to differentiate between the influences of these distinct pathways. The dorsal stream processes visual information for motion whereas the ventral stream is responsible for mental representations of visual information. One theory suggests that movement is primarily modulated by dorsal stream processing, whereas others believe that the ventral pathway influences motor judgments [2]. It is important to resolve these issues in order to identify sensory-motor dysfunction in pathologies such as Autism, Parkinson's, and Schizophrenia [3]. It is therefore imperative to establish a basic understanding of visuomotor processing in order to develop sensory-driven therapies in the future to treat these conditions.

The Laboratory of Vision Research & The Sensory Motor Integration Laboratory intend to clarify these issues. We study visuomotor processing using a 3D visual stimulus. It creates a bistable percept that allows us to study how the ventral and dorsal pathways affect motor control. Motor control is defined as the physical actions that are a executed to perform a given task based on sensory inputs such as visual feedback. By implementing the visual illusion in a reach-grasp task, we can investigate how the vision-for-perception pathway influences motor behavior.

Methods

Our study utilizes two main stimuli in order to evoke ventral and dorsal stream processing (see Figure 1): a reverspective (R) and a properspective (PE).

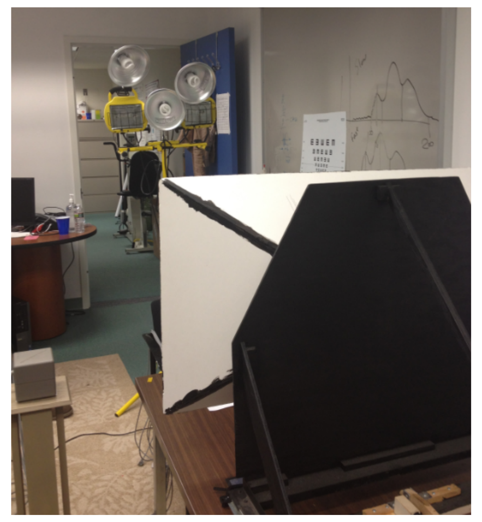

Figure 1: Experimental Setup

An R, or reverse perspective is a 3D visual illusion, that when viewed from certain distances, can elicit a bistable percept (illusory (RI) or veridical (RV)). A PE, or proper perspective, is a 3D visual stimulus that recapitulates the veridical geometry that would be seen if the illusory percept is evoked from R. Targets were placed on the stimuli and subjects were asked to grasp/reach towards the target under the influence of 1 of 3 conditions: RI, RV, or PE.

To ensure this, we constructed a system that:

1. Allows the subjects to reach for a target on the stimulus in order to study their reaction to the percept,

2. Does not allow the subject to come into contact with the stimulus, and

3. Does not allow the subject to make micro adjustments to their reach path as they approach the target

To do so, we utilize an Arduino microprocessor to control the lights in the environment and to retract the stimulus set on a rail through a Matlab program to reduce the number of visual cues. 3 baseline, 8 training, and 36 experimental trials are executed. Furthermore, the full motor trajectory of the subject's arm is recorded using the Motion Monitor, a motion analysis system to study six degrees of freedom (based on the x-y-z locations along with roll, pitch, and yaw).

Preliminary Results

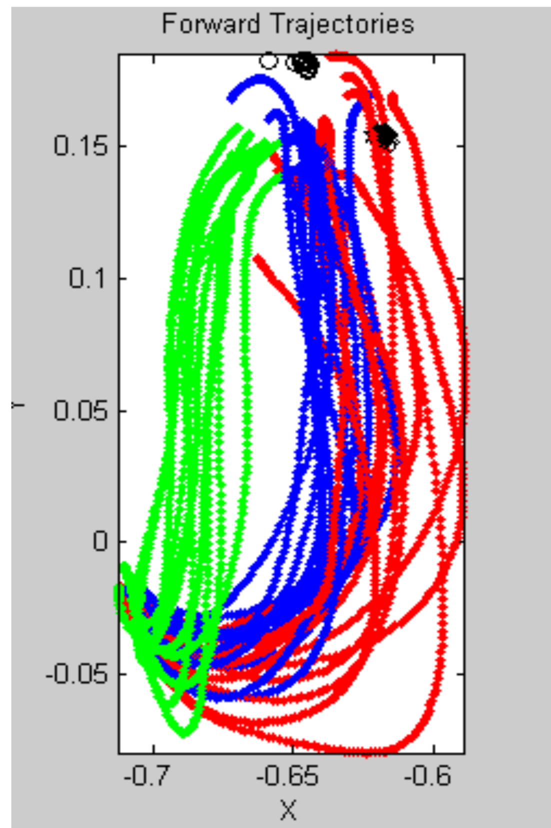

Figure 2 - YB

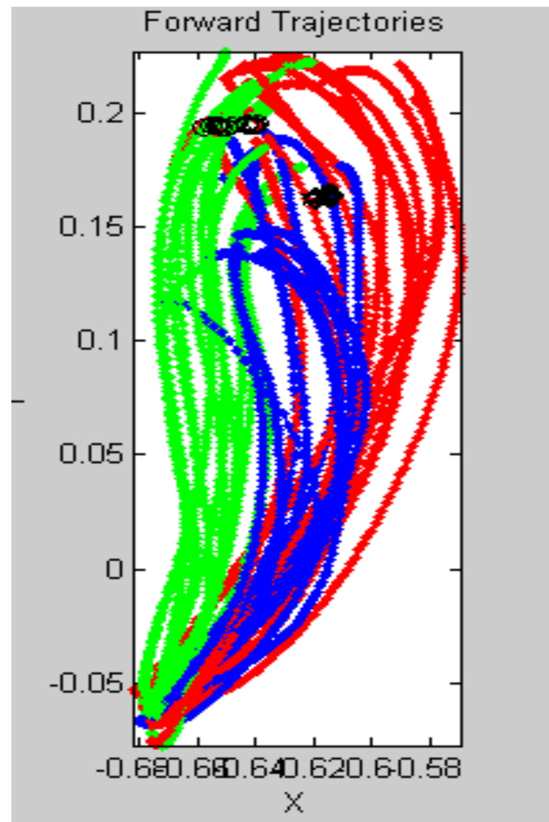

Figure 3 - JJ

The figure demonstrates the effects of the stimulus on Subject YB's and Subject JJ's reach trajectories.

Reverspective - Veridical
Reverspective - Illusory
Properspective - Veridical

Based on the results of this trial, there seems to be a strong effect induced by the reverspective and properspective. Specifically, there is a distinct difference between full movement trajectories of the reverspective viewed in the veridical condition, compared to when it is viewed in the illusory condition.

The subjects' illusory trajectory paths were similar to the properspective. Further statistical analyses must be performed in order to verify the robustness of these results of visual inspection.

Furthermore, more subjects need to be run to further investigate the mechanisms behind these results.

Discussion

This study differentiates itself from previous work in the field such that it analyzes full movement trajectories of the arm to effectively deduce the influence of visual perception on motor behavior. Our preliminary data suggest a robust effect of the illusory percept on the reach-grasp task, providing evidence for ventral stream modulation.

Our study may in fact refute the claim that motor processing relies on the dorsal "vision-for-action" pathway [2]. Understanding how perception influences motor control will help us develop models of normative visuomotor behavior which can then be compared to models we intend to build based on sensory-motor dysfunction in pathologies such as Autism, Parkinson's, and Schizophrenia. This in itself will generate key information that can be used in translational research for the development of sensory-driven therapies that target specific areas of the brain that are under study.

Future Directions

We look forward to gathering more data on additional subjects and performing statistical analyses on the results to confirm the strength and validity of our visual observations. Once a normative model can be built using these data, we intend to test populations that suffer from sensory-motor dysfunction to identify how these disrupted systems differ from typical visuomotor control. We also aim to incorporate an eye tracking system in conjunction with the reach-grasp task to provide a more robust perception and action model.

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References

[1] Gegenfurtner K, et al. (2011). Recent advances in perception and action. *Vision Research*, 51:801-803.

[2] Milner AD & MA Goodale (2008). Two Visual Systems: Re-Viewed. Neuropsychologia 46 (2008) 774–785

[3] Uhlhass PJ, et al. (2006). Neural synchrony in brain disorders: relevance for cognitive dysfunctions and pathophysiology. *Neuron*, 5; 52(1):155-68.