# Late integration of vision and proprioception during reach perturbations

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## Abstract

The motor system corrects rapidly, but selectively, for perturbations to ongoing reaching movements, depending on the constraints of the task. To account for such sophistication, it has been postulated that corrections are based on the estimated limb state that integrates all sensory changes caused by the perturbation, taking into account their processing delays. Here we asked if information from different sensory modalities are integrated immediately, or processed separately in the first instances of a response.

We perturbed the estimated state of the limb with both uni-modal and bimodal visual and proprioceptive perturbations without changing the limb location. For visual perturbations, a cursor representing the hand was shifted to the left or the right relative to the true hand location. For proprioceptive perturbations, the biceps or triceps muscles were vibrated, which induced illusory limb state changes to the right or left. In the bimodal condition the perturbations to vision and proprioception were either congruent or incongruent in their directions.

Response latencies show that it takes ~100 ms longer to initiate a response to the visual cursor manipulations than to the muscle vibration. Responses in the bimodal perturbations show that inter-modal consistency of the perturbation directions only had an impact after an additional ~100 ms beyond the response latency of visual cursor manipulations.

These results suggest that visual and proprioceptive signals are initially processed separately for state estimation and only combined at the level of the limb's motor output, instead of being immediately integrated into a single state estimate of the limb.