Late integration of vision and proprioception during reach perturbations

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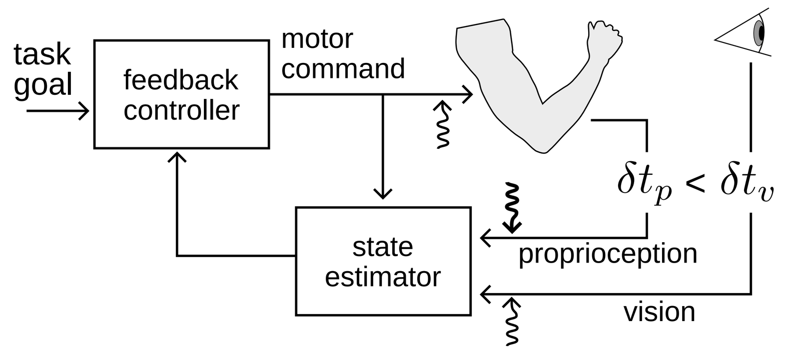
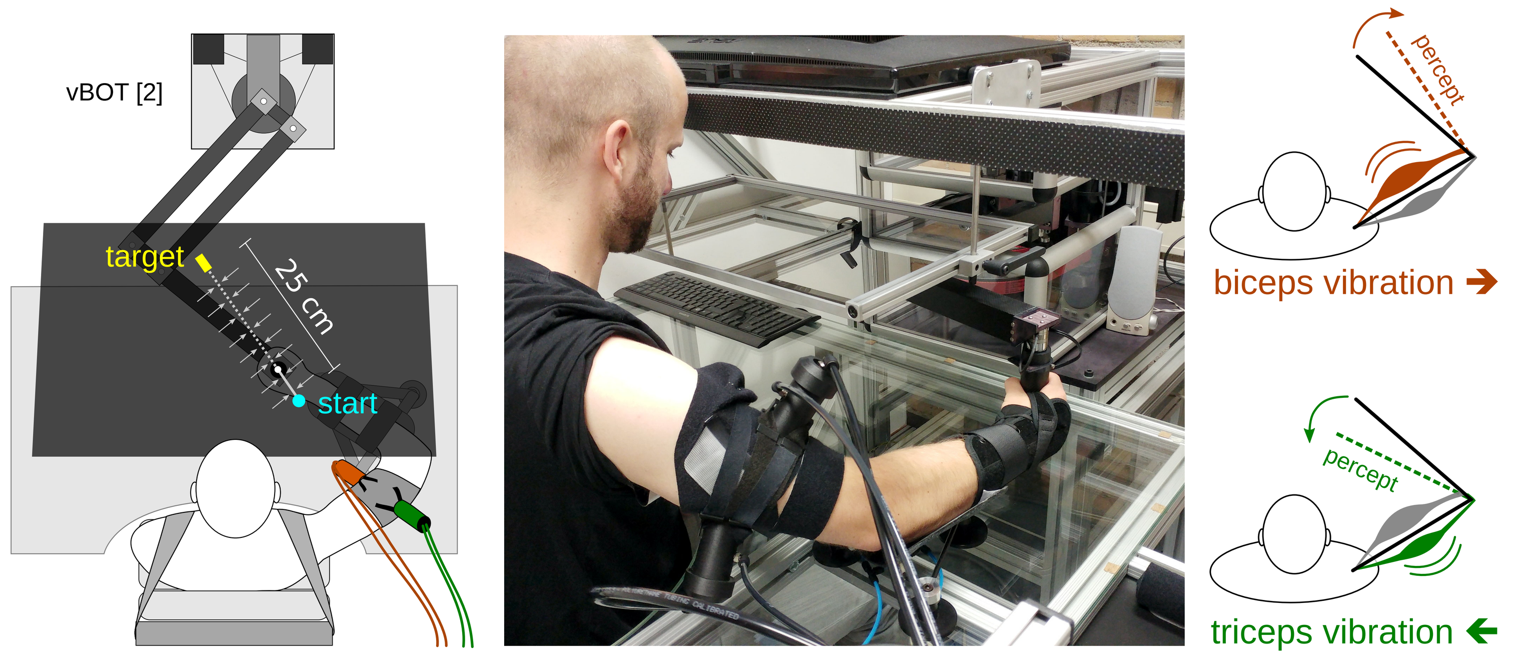
INTRODUCTION

- The motor system rapidly corrects for perturbations during an ongoing reach, in a task-dependent manner [1].
- Supposedly, these corrections are based on a multi-sensory estimate of the limb state [3, 4].
- Multi-sensory, time-dependent state estimation requires the incorporation of sensory latencies [3].

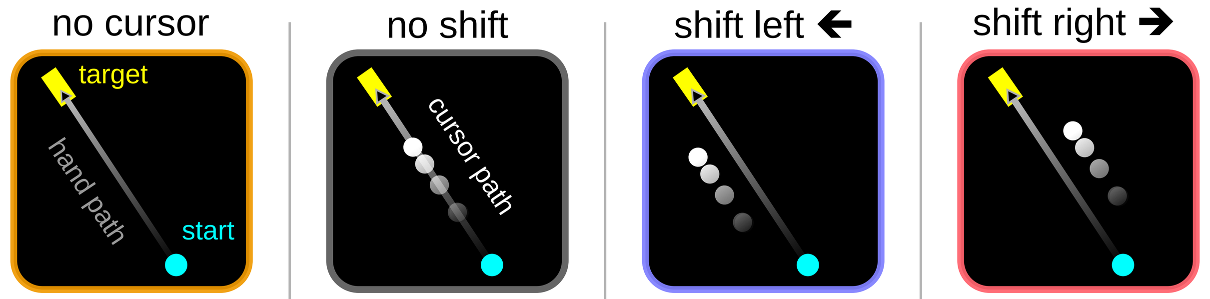
Here we asked if information from different sensory modalities is integrated immediately, or processed separately in the first instances of a response.



PARADIGM



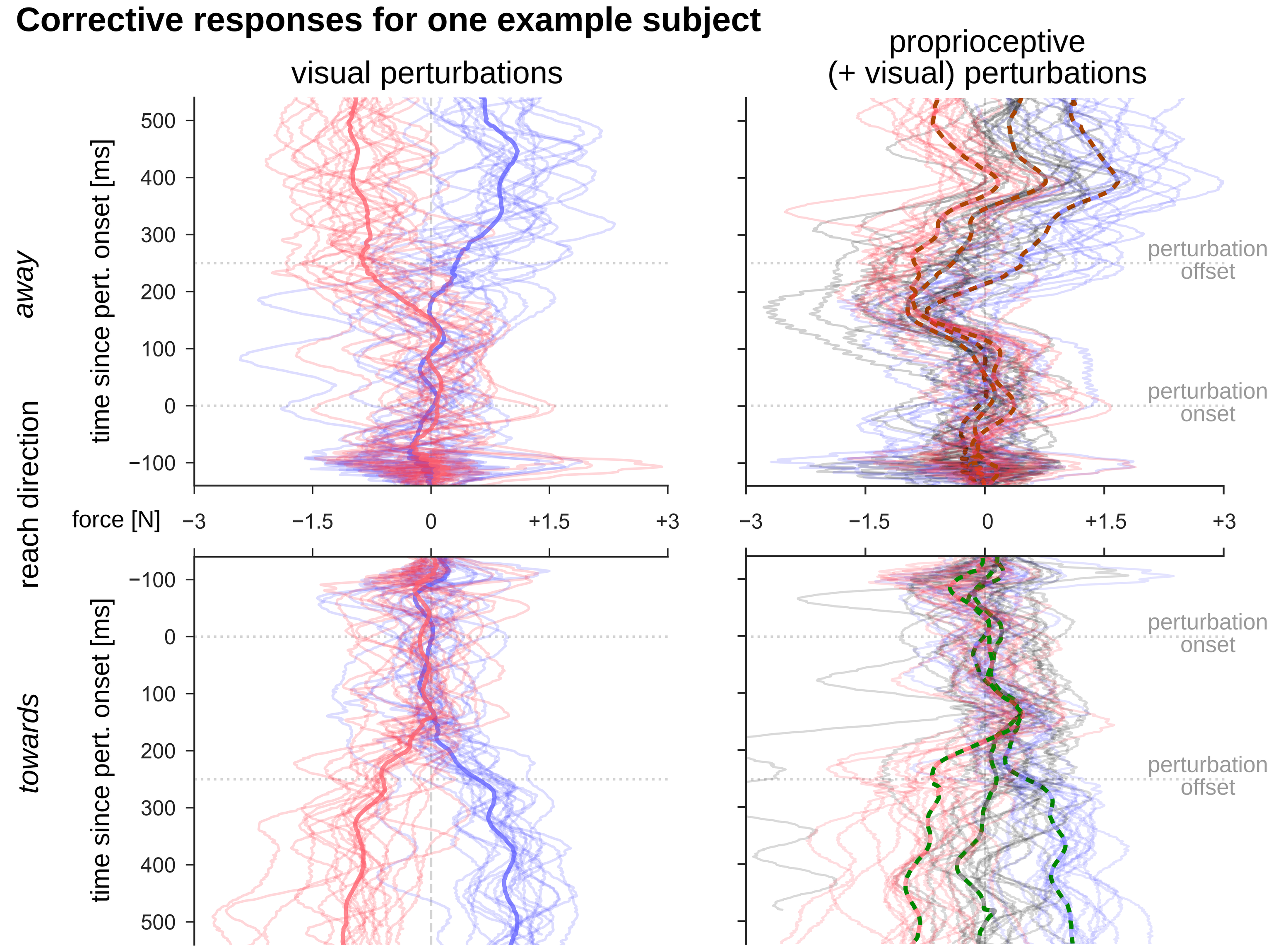
- 22 subjects each performed 640 trials in 1 session (320 free, 320 with error clamps).
- **Proprioceptive perturbations:** The biceps or triceps muscles were vibrated (for reaches *away* and *towards* the body, respectively) to induce illusory changes of limb state in **extension** [➔] or **flexion** [🡐] direction.
- **Visual perturbations:** A **cursor** representing the hand was flashed to the **right** or **left** from the true hand location.
- **Bimodal perturbations** were either **congruent** or **incongruent.** We used the interaction effect of Baysian ANOVAs (vibration × cursor) as a proxy for multi-sensory integration of responses to bimodal perturbations.



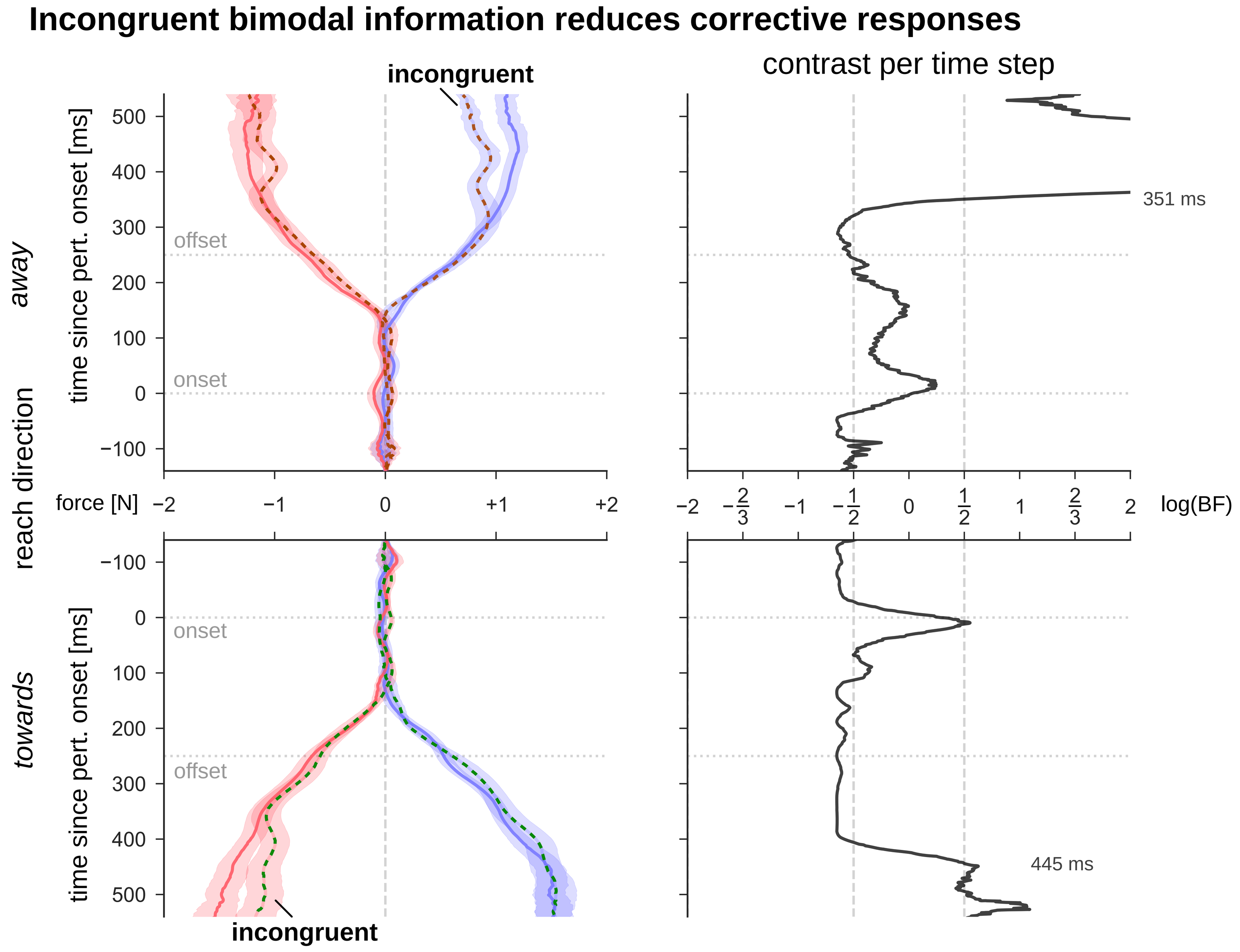
	no cursor	no shift	shift left 🡐	shift right ➔
no vibration	no vision veridical propr.	veridical vision veridical propr.	vision 🡐 veridical propr.	vision ➔ veridical propr.
biceps vibration ➔	no vision propr. ➔	veridical vision propr. ➔	**incongruent** vision 🡐 propr. ➔	**congruent** vision ➔ propr. ➔
triceps vibration 🡐	no vision propr. 🡐	veridical vision propr. 🡐	**congruent** vision 🡐 propr. 🡐	**incongruent** vision ➔ propr. 🡐

RESULTS

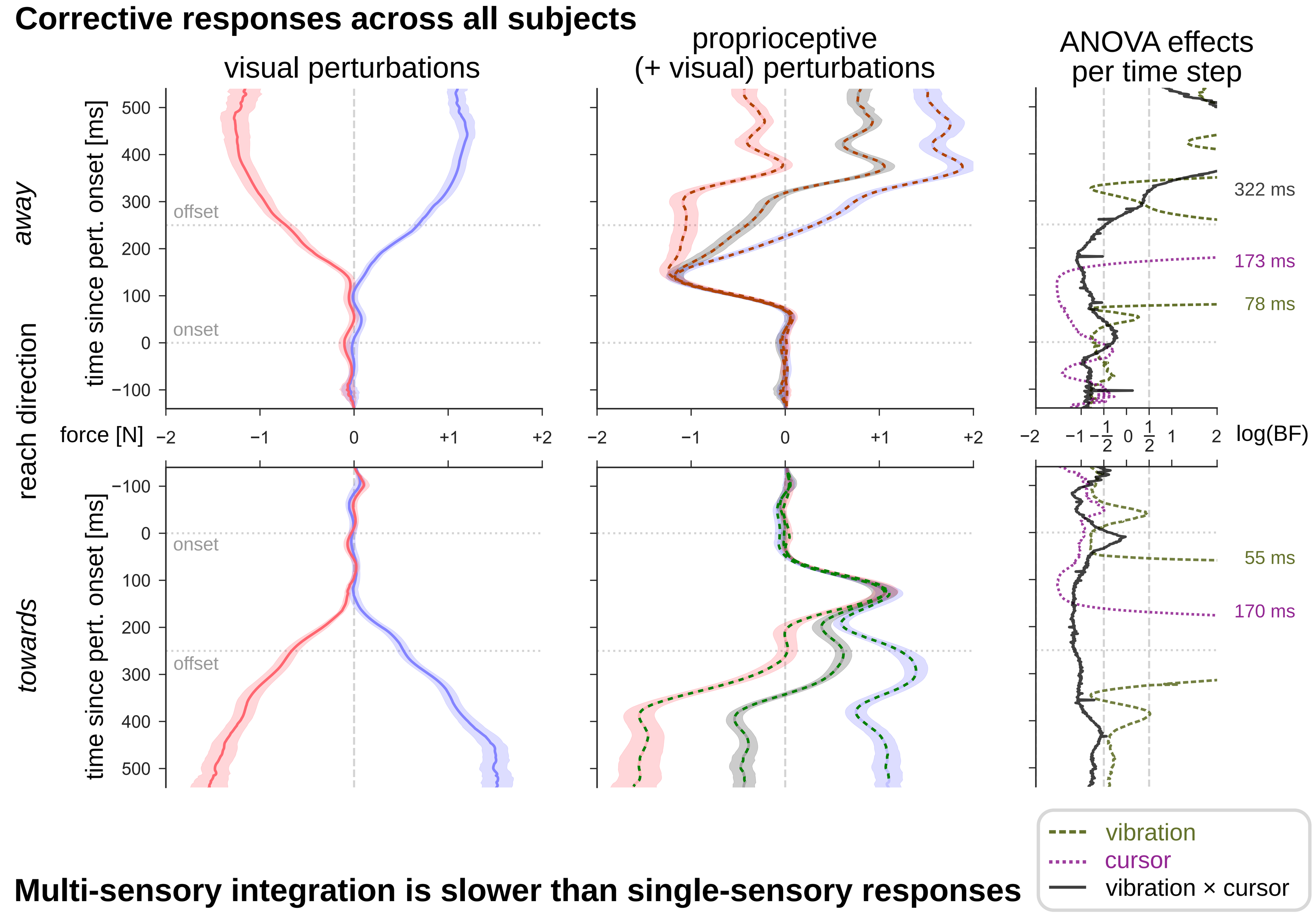
Corrective responses for one example subject



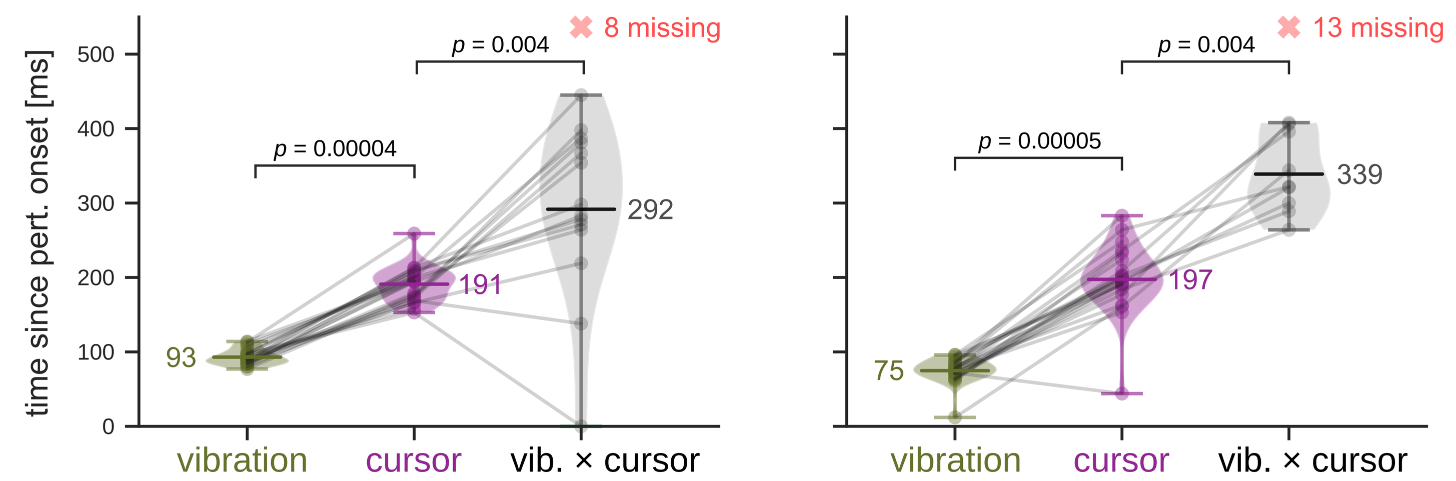
Incongruent bimodal information reduces corrective responses



Corrective responses across all subjects



Multi-sensory integration is slower than single-sensory responses



CONCLUSIONS

- It takes ~100 ms longer to initiate responses to visual perturbations (cursor shifts) than to proprioceptive perturbations (muscle vibration).
- It takes an additional ~100 ms to integrate the visual and proprioceptive signals, arguing against optimal integration based on a Kalman filter [3] (but consistent with [4]). This indicates unimodal contributions for the initial stages of the response [5].

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