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Causal inference in the updating and weighting of allocentric and egocentric information for spatial constancy during whole-body motion

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It has been reported that the brain combines egocentric and allocentric information to update object positions after an intervening movement. Studies typically use discrete updating tasks (i.e., comparing pre- to post-movement target representations). Such approaches, however, cannot reveal how the brain would weigh the information in these reference frames during the intervening motion. A reasonable assumption is that objects with stable position over time would be more likely to be considered as a reliable allocentric landmark. But inferring whether an object is stable in space while the observer is moving involves attributing perceived changes in location to either the object's or the observer's displacement. Here, we tested this causal inference hypothesis by designing a continuous whole-body motion updating task. At the beginning of a trial, a target was presented for 500 ms, within a large visual frame. As soon as the target disappeared, participants were asked to move a cursor to this location by controlling a linear-guide mounted on the vestibular sled on which they were seated. Participants were translated sideways as soon as their reaching movement started, and they had to maintain the cursor on the remembered target location in space while being moved. During the sled motion, the frame would move with a velocity proportional to that of the sled (gain ranging from -0.7 to 0.7). Participants' responses showed a systematic bias in the direction of the frame displacement, one that increased with the difference between the frame and the sled velocity for small differences, but was decreasing for large differences. This bias pattern provides evidence for humans exploiting a dynamic Bayesian inference process with two causal structures to mediate the dynamic integration of allocentric and egocentric information in spatial updating.

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