
Influence of virtual reality on body schema and peripersonal space

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Résumé

Introduction

Prism adaptation is a well-established paradigm used to induce a sensorimotor discrepancy (Kornheiser, 1976). When subjects wear glasses that shift the visual field during pointing tasks, the seen position of the hand is displaced relative to its actual position. Upon removal of the glasses, aftereffects emerge as pointing errors in the opposite direction of the optical shift.

Unlike prismatic glasses, which create uniform visual deviations, virtual reality (VR) offers broader possibilities. It enables the induction of extreme, non-homogeneous distortions and provides fine control over visual feedback (Lenggenhager et al., 2007).

This technological potential led us to develop a VR-based paradigm designed to induce asymmetrical sensorimotor perturbations and assess their effects on both motor behavior and spatial representations.

Method

We developed two tasks tailored for head-mounted VR displays:

- **Ball task:** A virtual version of a classical peripersonal space (PPS) assessment paradigm. Participants observed a ball moving back and forth and indicated when they perceived it as entering or exiting their reachable space. The ball followed three trajectories: sagittal, 45° left, and 45° right. The distances reported by participants allowed estimation of their PPS boundaries (the space the brain considers as near), as opposed to extrapersonal (far) space.
- **Cube task:** A visuomotor pointing task based on the VR headset's hand-tracking. Participants reached toward virtual cubes placed at various distances along the same three directions. Crucially, a directional motion gain was applied: hand movements were visually amplified in one hemifield and reduced in the opposite, generating an asymmetrical perturbation. Different configurations of gains and hemifields were used.

PPS was measured in all directions before and after exposure to the gain manipulation. Sensorimotor adaptation was evaluated via open-loop conditions in the cube task, with visual hand feedback removed.

Results

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In a first experiment, we observed open-loop pointing adaptations consistent with the motion gain: hypometric movements on the side with increased gain and hypermetric on the side with reduced gain.

Given the known asymmetry of cognitive and executive function distribution, we reversed the gain configuration in a second experiment and replicated the pattern.

In terms of visuospatial representations, the ball task showed a PPS reduction on the side with reduced gain, but no PPS extension was observed on the opposite side under any condition.

To further explore this asymmetry, we conducted three control experiments with uniform gain manipulations (reduced, unchanged, and increased). Sensorimotor adaptations were again observed, but no PPS expansion occurred, even in the increased gain condition.

Discussion

Our findings suggest that VR is a robust paradigm to induce sensorimotor adaptations akin to those produced by prism adaptation. The novelty lies in the asymmetrical nature of the perturbation: it appears that the nervous system can simultaneously integrate two distinct, hemifield-dependent sensorimotor adaptations.

However, the absence of PPS expansion raises questions about the conditions needed to alter spatial representations. It is possible that the amplified gain was too extreme to be integrated into the body schema. Furthermore, the absence of a virtual arm linking the tracked hand to the body (Linkenauger et al., 2015), combined with minimal visual landmarks, may have limited participants' ability to evaluate distances, which is a key factor in modifying body and space representations (Mine et al., 2020).

Conclusion / Perspectives

This study demonstrates the possibility of inducing asymmetric adaptations, both in visuospatial coordination and in spatial representations. Building on these findings and the versatility of VR, we aim to design novel neurorehabilitation paradigms for patients with impaired spatial representations. These results also highlight the need for more immersive and context-rich virtual environments in future work to better support the remapping of body and space.

References

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