

Abstract

The visual scene on the eyes expands outward during walking. Such visual information is not only used to detect obstacles on the pathway, but is actually used to control walking in real time. Here we show that **our automatic regulator of walking speed based on vision, which estimates and maintains the speed, is robust to changes in the depths.** The robustness was not explained by temporal-frequency-based speed coding previously suggested to underlie depth-invariant object-motion perception. On the other hand, it broke down, not only when interocular distance was virtually manipulated, but also when monocular depth cues were deceptive. These observations suggest that **our visuomotor system embeds a speedometer that calculates self-motion speed from vision by integrating monocular/binocular depth and motion cues.** Elucidating these implicit visuomotor control mechanisms will help us for refining the technology and safety design of virtual reality devices.

How is walking speed controlled?

- Human can walk in a constant speed by moving legs.
- To do so, the brain uses sensory information monitoring muscle and limb states and head motion. Visual information is also indispensable to avoid obstacles on the load.
- Additional **visual function** is known to be used **for walking speed regulation.**

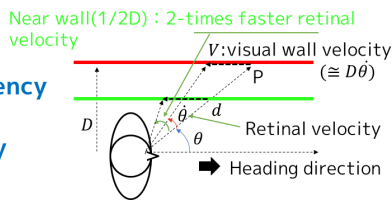


What information is coded in the brain for walking speed regulation?

Hypo1: Retinal velocity

Hypo2: Temporal frequency of retinal image

Hypo3: Walking velocity

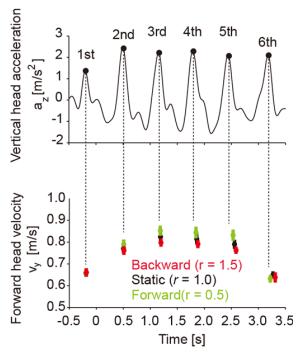
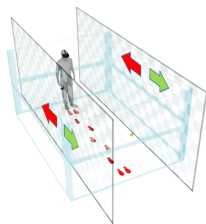


Wall motion impacts on walking speed

The head-mounted display (HMD) shows a passageway with virtual walls, and a person is instructed to walk through it.

Walking speed increases when the wall is moved forward during walking, and vice versa (automatic gait speed regulation).

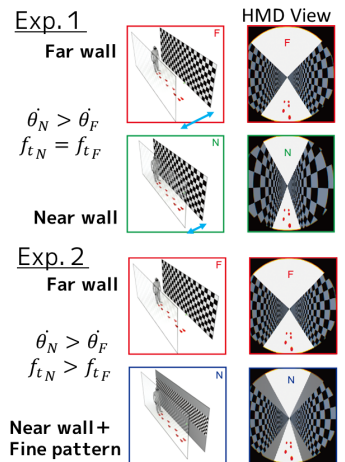
⇒ Index: Walking-velocity-change



Vision based walking speed regulation

Q1: Does the retinal velocity or visual temporal frequency regulate walking speed?

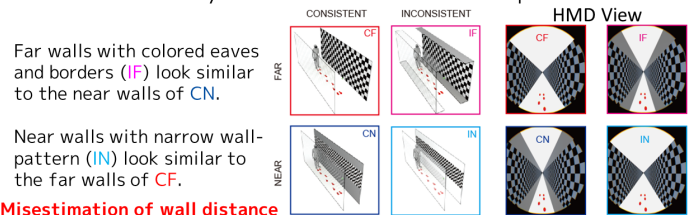
Three hypotheses were examined by walking experiments with different wall-distances and roughness of wall patterns.



Experimental data showed that walking-velocity-changes were not different under two conditions of Exp1 nor of Exp2, supporting Hypo3.

Q2: Does the monocular depth cue contribute to the wall distance estimation needed to calculate walking speed?

Walk under some conditions where the wall distance tends to be misestimated by binocular and monocular depth cues.



Misestimation of wall distance

⇒ Experimental data showed that misestimation of wall distance results in alteration of walking-velocity-changes.

The brain automatically estimates walking speed for gait control using visual information.



References

[1] S. Takamuku, H. Gomi, "Vision-based speedometer regulates human walking," *iScience* 24:103390, 2021. <https://doi.org/10.1016/j.isci.2021.103390>.

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