

PERSPECTIVES

Unveiling visuomotor control of bipedal stance, step by stepKei Masani^{1,2} and Albert H. Vette^{3,4}¹Rehabilitation Engineering Laboratory, Institute of Biomaterials and Biomedical Engineering, University of Toronto, 164 College Street, Toronto, Ontario, Canada, M5S 3G9²Rehabilitation Engineering Laboratory, Lyndhurst Centre, Toronto Rehabilitation Institute – University Health Network, 520 Sutherland Drive, Toronto, Ontario, Canada, M4G 3V9³Department of Mechanical Engineering, University of Alberta, 10–203 Donadeo Innovation Centre for Engineering, 9211-116 Street NW, Edmonton, Alberta, Canada, T6G 1H9⁴Glenrose Rehabilitation Hospital, Alberta Health Services, 10230 111 Avenue NW, Edmonton, Alberta, Canada, T5G 0B7

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You are sitting on a train at a station. Another train beside you starts moving. You may have an illusion that you are moving instead. If you are standing at that time, your body may *tilt* due to this illusion. A study by Day *et al.* (2016) in this issue of *The Journal of Physiology* unveils that this postural response to visual-field motion is not one simple reaction, but a series of two reactions stemming from different visuomotor pathways controlling bipedal standing balance. This finding further demonstrates the large emphasis our brain puts on the visual modality when regulating postural balance – and this in spite of the ambiguous information it provides.

Vision is a very strong influencer of posture. The brain has three primary sources of sensory information at hand, i.e. the visual, vestibular and somatosensory systems. While all available sensory information is integrated for controlling posture, the contribution of each source is flexibly weighted dependent on a given situation. Among these sensory systems, our brain puts strong emphasis on visual information when stabilizing the human body. For example, when we stand in a room whose walls start oscillating, our bodies will start to oscillate following the walls' oscillations even if the other two sensory

sources report our bodies' motionlessness to the brain. This so-called moving room paradigm signifies the uniqueness of the visual modality among the three sensory systems: that is, while the other two systems are designed to always report on any form of self-motion, the visual system does not necessarily do so. In fact, motion registered in the visual scene can be associated with self-motion, motion of external objects, or both. Thus, to effectively use visual information in controlling posture, the brain needs to extract reliable information on self-motion from the registered motion in the visual scene. In spite of this contextual requirement, vision plays a critical role in postural control – presumably due to the fact that it is the only modality that can evaluate head orientation with respect to the environment.

Within this research domain, Day *et al.* (2016) moved our understanding one step forward by applying a discrete visual-field motion instead of a continuous oscillatory one that has been used in the majority of related studies. It is surprising and noteworthy that the paradigm of exploiting a discrete visual-field motion is novel in this research area. While the two postural responses found in this study are presumably also present during continuous visual-field motion as a transient phenomenon, Day *et al.* were able to isolate them with their approach. They discovered the existence of two consecutive components in the postural response to discrete visual-field motion: the *early-phase response* occurs with a latency of about 0.19 s, and the *late-phase response* with a surprisingly long latency of about 0.7 s. On the one hand, the early-phase response quantifies both the initial, fast reaction to the induced visual-field motion and the compensatory reaction based on further sensory information. This early-phase response is smaller when the visual-field motion is faster as the brain can more quickly rule out the presence of self-motion. On the other hand, the late-phase response continues to deviate the body away from vertical during the applied discrete visual-field motion. Day *et al.* speculate that the late-phase response is caused by the brain's erroneous estimate of gravity direction. This interpretation borrows from Dichgans *et al.* (1972) who

found that a continuous visual-field motion distorts the brain's estimate of gravity direction, used to orientate the body in space. The response to such distortion is accompanied by a latency that agrees with the late-phase response found by Day *et al.* A faster visual-field motion may induce a larger error in estimating the gravity direction and, hence, the body's orientation. As a result, the late-phase response is augmented, obeying an opposite relation to visual-field speed than the early-phase response.

Posture is controlled using information via cascaded loops of three major sensory systems, each of which involves different sensorimotor latencies. In addition, the uniqueness of visual information requires the brain to extract potential self-motion from registered visual-field motion. Such extraction may utilize a Bayesian model (Dokka *et al.* 2010), which could entail additional computational delays within the sensorimotor loop. The cascaded loops of the complex sensory systems and the unique need for interpreting visual information can account for the two temporally separated postural responses with different characteristics, which resemble short- and long-latency stretch reflexes. However, the question of what causes the late-phase response may not be fully answered within Day *et al.*'s study, and the underlying mechanisms remain unknown. Is it really true that the late-phase response is due to the error in gravity direction estimation, induced by the visual-field motion? And why does this response start relatively late following motion onset? Characterizing the two responses with theoretical or computational approaches that succeed in describing the cascaded mechanisms of sensory integration (Peterka, 2002) would certainly help to fully unveil the cascaded structure of visuomotor control of human posture.

Since bipedal stance is employed solely by humans, we cannot use animal models to explore underlying control mechanisms. Thus, scientists are forced to adopt black-box approaches to study human bipedal stance, which – to be honest – frustrates us. The study by Day *et al.* provides a new clue for how to unlock this particular black box. In this way, the fundamental question of why such

ambiguous visual information is critical in controlling bipedal stance will be solved in the near future; step by step.

References

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Additional information

Competing interests

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Author contributions

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