

## Visually Guided Human Adaptive Locomotion

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Locomotion, such as walking, running, or using an automobile or a wheelchair, is the behavior of moving one's body toward a desired place. During locomotion, the critical role of the central nervous system (CNS) is not only to propel the body in the intended direction but also to maintain balance (i.e., not to fall). A challenging aspect of maintaining balance during locomotion is that the CNS accommodates changes in the constraints of spatial environment. When confronting an obstacle, for example, individuals need to control the displacement of the center of mass (COM) to either step over the obstacle, change direction, or even stop walking. Navigating through a narrow opening requires modification of locomotor patterns if the size of the opening is too small relative to the body. Locomotion while modifying the basic movement patterns to propel in response to environmental constraints is referred to as adaptive locomotion.

To maintain balance with these challenging aspects, the CNS takes both a reactive strategy to deal with unexpected perturbation and a pre-planned strategy to avoid potential perturbation a priori. A pre-planned strategy is further divided into predictive and anticipatory strategies [1]. A predictive strategy refers to the maintenance of inter-segmental stability within the body or between the body and surface based on the estimation of expected perturbation generated by ongoing movements. The predictive strategy is therefore used to regulate locomotion on a local level (i.e., a step-by-step basis). In contrast, an anticipatory strategy refers to the maintenance of balance on a more global level (i.e., sustained over several steps). Locomotor patterns are modified on the basis of visual information about environmental properties at a distance to avoid a future perturbation altogether.

While vision plays an important role on all of the reactive, predictive, and anticipatory strategies, the anticipatory strategy is driven exclusively by vision. This is because vision provides the spatio-temporal information regarding a remote place very precisely. Understanding the anticipatory nature of the adaptive locomotion is, therefore, particularly helpful to understand how vision is used to adaptively control our locomotion.

Adaptive locomotor adjustments in response to environmental constraints, such as the existence of an obstacle are initiated when an

obstacle is still in far space [2]. For example, when participants were asked to step over two obstacles located 1m apart, their foot placement to take off prior to the first obstacle was closer to the obstacle than when they were stepping over a single obstacle [3]. This is an understandable method in order to obtain a better take-off position prior to a second obstacle and suggests that the modification of limb movement for avoiding the second obstacle was already initiated before stepping over the first one.

To assist such anticipatory adjustments, visual information about far space is necessary. Analyses of spatio-temporal patterns of gaze behavior during adaptive locomotion under a variety of environments, as well as under a variety of forms of locomotion, have shown that fixations are generally directed toward far space. The basic rules are that we are looking at far space and that "we are moving as we are looking" [4]. More specifically, the majority of fixations are directed either toward a desired future path or toward an object of interest.

The inability to rely on anticipatory strategy to control adaptive locomotion with age can result in increased fall risk. Both older individuals who are at high risk of fall and some stroke patients who directed their fixation closer toward their lower limbs exhibited altered fixation patterns. These altered patterns are likely to indicate that they need on-line visual information about the environment surrounding the leading limb to ensure precise stepping. This, in turn, suggests that they have difficulty using the visual information regarding the environment in a feed-forward manner and modify their locomotor patterns in an anticipatory manner, which could cause perturbation when confronting an obstacle.

### References

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