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Let the machine do the work: learning to reduce the energetic cost of walking on a split-belt treadmill

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The human body is capable of exploiting mechanical work provided by the external environment. A simple everyday example is the assistance provided by gravity when walking downhill, which can decrease energy cost. In recent decades, there have been numerous attempts to exploit this phenomenon in the form of wearable devices like powered exoskeletons, which can reduce the energy cost of walking (e.g. Malcolm *et al.* 2013). Such devices could eventually be of value to various human populations, including ageing individuals and those with gait-related impairments.

Unfortunately, optimal energy savings cannot be obtained by simply attaching a powerful motor to the ankle joints. Whilst the amount of work provided by an external device is of course important, an individual must also learn to modify his or her gait in a way that actually takes advantage of the additional work, thereby decreasing the amount of positive work that the muscles must produce (Zhang *et al.* 2017).

Fortunately, it seems that people can learn to take advantage of extra work, at least to some extent, and this can result in a lower energetic cost of walking. A common model in studies examining the learning process involves the use of a split-belt treadmill, whereby individual belts drive each limb at different speeds. In theory, this set-up enables a person to learn to extract net mechanical work from the treadmill, and thereby reduce the energetic cost of walking. Indeed, this phenomenon is elegantly demonstrated by the recent study of Sánchez *et al.* (2019) in this issue of *The Journal of Physiology*.

Sánchez *et al.* examined whether the learning process associated with walking on a split-belt treadmill can be explained as a process by which people learn to take advantage of work performed by the treadmill. In other words, does the neuromotor system modify split-belt gait in order to reduce energy cost? To answer this question, they first used visual feedback to train participants to walk at different levels of step length asymmetry, i.e. different step lengths of the leg and right legs. These levels ranged between −0.15 and +0.15, where negative values correspond to longer steps with the leg that contacts the slow treadmill belt, and positive values denote longer steps with the leg contacting the faster belt. The purpose of this part of the protocol was to expose participants to conditions that were expected to have different energy costs (metabolic cost was also quantified). In the second part of the experiment, participants simply walked on the treadmill without any instructions. Here the researchers wanted to test whether participants converged towards the most metabolically optimal conditions found in the previous set of trials.

As predicted, when transitioning from step length asymmetries of−0.15 to +0.15, there was an increase in the net positive work performed by the treadmill on the person, and a corresponding decrease in the net positive work performed by participants. This was accompanied by a decrease in the metabolic cost of walking of around 14%. Essentially, the treadmill acted as an assistive device at positive step length asymmetries, and participants were able to take advantage of this assistance.

Interestingly, in the ‘free’ adaptation trial that followed the initial learning trials, participants chose to walk at a level of asymmetry that was close to that which minimised metabolic cost in the preceding trials. In effect, after being exposed to conditions with different energy costs, participants quickly learned to use the condition that was most metabolically optimal without any prompting by the researchers. This finding nicely demonstrates the advantage of Sánchez *et al.*’s experimental paradigm over previous approaches for examining the adaptation process. Usually, participants require multiple test sessions before learning to take longer steps on the fast belt (Leech *et al.* 2018), and this may involve several days of experiments. Conversely, in Sánchez *et al.*’s protocol, participants merely needed a short exposure to each condition, which has obvious advantages if this approach were to be used with participants who have difficulties walking.

Sánchez *et al.*’s study demonstrates that humans can quickly learn to take advantage of external mechanical work, and that the learning process is driven by an attempt to reduce energy cost. However, some questions remain unanswered. For example, participants were only able to use net treadmill positive work with an efficiency of around 33%, and it is not yet known whether this can be improved. Moreover, for logistical reasons, the authors only examined conditions performed at a fixed stride length, so it is possible that allowing participants to change their stride length could also influence adaptation and the associated energy savings. Finally, it seems likely that the adaptation process is somewhat individual (cf. the scatter of points in Figs 7 and 8 of Sánchez *et al.* (2019)). Importantly, the paradigm presented by Sánchez *et al.* could be used to address all of these questions in the future.

In summary, Sánchez *et al.* present an innovative model for examining the process of adaptation to asymmetrical gait conditions in a time-efficient way. Such a model could have important applications in the future, where the need for energy-saving devices – and knowledge about how humans can optimally exploit them – is likely to increase as the global population continues to live longer and walk well into old age.

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