**Effort and locomotor learning (split-belt adaptation)**

***Experimental Brief***

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*Question*: How do differences in physical effort affect motor learning and savings in split-belt locomotion?

*Predictions*: In a high effort condition, the benefit of reducing metabolic cost increases, if this increased benefit partly drives motor learning, adaptation will be faster in the high effort condition. If, on the other hand, effort impairs learning, the higher effort cost will slow adaptation.

When normal movement is disrupted by an external perturbation, the brain quickly adjusts the movement to compensate for external conditions. In general these adjustments are attributed to error reduction via feedback control in the brain; however, research in reaching (Huang et al. 2012) and split-belt walking (Sánchez et al. 2019, 2021) shows that metabolic cost is reduced in parallel with error reduction during the learning process. We also observe that humans are willing to adjust their walking (in this case walking speed) away from preferred in order to reduce metabolic cost (Selinger et al. 2015).

We compare learning and savings by looking at error reduction curves. When the external perturbation is introduced (the split belt speeds in this case), people have an abrupt increase in error (asymmetry) when there is no compensatory learning to counter the error introduced. Over time, people reduce their error, adjusting their movement to counter or accommodate the perturbation (Fig. 1 top). Learning is characterized using the shape of the error reduction curve – faster error reduction (steeper descending slope) indicates faster learning. The error reduction generally reaches an asymptote after a long enough adaptation phase. Following the adaptation phase, we switch to a washout block wherein the external perturbation is removed. Washout should be long enough that performance returns to baseline levels. After washout, we can look at savings, a measure of how much of the adaptation is stored from the initial learning block. In the savings block, we reintroduce the external perturbation and again examine the error reduction over time. By comparing the error reduction curve from learning to that from savings (Fig. 1 bottom), we measure how much faster the error is reduced in the second exposure.

We are comparing learning as differentiated by effort. Effort is a bit of a slippery term, but the gold standard measure is metabolic cost (indicating more energy burned to complete the task. In our experiment, we are not measuring metabolic cost and rather are using added weight. Differences in metabolic cost during walking with added weight (Puthoff et al. 2006) as well as in split-belt walking, where the introduction of the different belt speeds increases metabolic cost (Butterfield and Collins 2022).

In split-belt walking specifically, adaptation to the different belt speeds is observed in step length symmetry (Leech et al. 2018; Reisman et al. 2007), center of pressure (COP) symmetry (Gonzalez-Rubio et al. 2019), ground reaction force symmetry (Mawase et al. 2013). Other metrics for assessing split-belt walking are step position (the distance from the center of mass to the heel strike), step time, and trailing limb angle.

In our experiment, participants walk on a split belt treadmill in a baseline, learning, washout, and savings blocks for each of two effort conditions. Effort conditions are differentiated by added weight worn in a weight vest. The low effort condition is 5% of body weight and the high effort condition is 15% of body weight. During the walking task, we collect force plate data using the two force plates embedded in the treadmill and use the Plug-In Gait model for motion capture data. Primary outcome measures is step length asymmetry. The error reduction curve for step length asymmetry will be used to compare learning curves between high and low effort conditions and between learning and savings.

