Date

Dear Editor,

We are submitting the Registered Report, **“The role of movement consistency in locomotor use-dependent learning”**, to be considered for publication in *eNeuro*.

Repetition is an essential component of motor skill acquisition. Yet, even after skills are well-learned, repetition continues to impact movement patterns by reducing movement preparation time, increasing movement speeds, and, most relevant to the current Registered Report, biasing future movements to be more similar to repeated ones (Diedrichsen et al., 2010; Hammerbeck et al., 2014; Mawase et al., 2018). This “use-dependent” learning is distinct from well-studied forms of error-based learning, such as sensorimotor adaptation, in that it occurs independent of an error signal and is purely repetition-based. Thus, use-dependent learning is linked to Hebbian learning and considered a basic form of motor memory (Classen et al., 1998; Verstynen and Sabes, 2011).

To date, use-dependent learning has been almost exclusively studied in upper-extremity movements, and rarely looked at in lower-extremity activities. Conversely, sensorimotor adaptation using the split belt paradigm has been the primary focus of the locomotor learning field (Malone et al., 2012; Morton and Bastian, 2006; Reisman et al., 2005; Roemmich et al., 2016; Sánchez et al., 2019). This is surprising given that walking is, by definition, a repetitive, cyclical movement that is repeated until a destination is reached; thus, walking provides an excellent opportunity to study a repetition-based learning mechanism. Our recently published manuscript (Wood et al., 2020) represents an early attempt to understand use-dependent learning in walking from a mechanistic perspective. In this study, participants increased their stepping asymmetry in response to visual targets on a computer screen, causing them to walk with a limp. After several minutes of practice, when the participants were asked to return to normal walking without any visual feedback, we observed a use-dependent bias in the form of a limp in the direction of the practiced movements that persisted for more than 5 minutes. Importantly, this bias was similar when learning occurred with or without sensory prediction errors in the visual feedback (i.e., difference between expected and actual sensory feedback). This is a departure from the assumption that aftereffects in this paradigm was due to sensory prediction error (Cherry-Allen et al., 2018; French et al., 2018; Hussain et al., 2013; Kim and Krebs, 2012; Kim and Mugisha, 2014; Statton et al., 2016; Wood et al., 2020).

In the proposed Registered Report, we aim to extend prior work on use-dependent learning by examining constraints on this process during walking and providing a computational framework for understanding this basic form of learning. Through a combination of computational modeling, simulations, and a series of behavioral experiments, we directly tackle the question of how the consistency of movement patterns impacts use-dependent learning. We first provide two distinct computational accounts of how use dependent learning may arise. In the Adaptive Bayesian model, adopted from a study of reaching (Verstynen and Sabes, 2011), use dependent learning is framed as a process which combines quickly adapting prior probabilities of target (step) locations with current sensory estimates of where to step. Thus, the magnitude of the use-dependent bias is directly related to the consistency of the environment, or target locations. Our second model involves two processes acting in parallel: a strategic learning process that is active when the goal is to match step lengths to visual targets, and in parallel, a slowly updating use-dependent process that biases movements in the direction of immediately preceding movements (Diedrichsen et al., 2010). Critically, our strategy plus use-dependent model is much less sensitive to the consistency of the environment than the Bayesian model. Thus, we have designed a set of walking experiments that systematically vary environmental consistency and assess the state of use-dependent biases during no-feedback trials in order to discriminate between these two competing theories on the underlying constraints of use-dependent learning.

We currently have approval from the University of Delaware Institutional Review Board to perform this work. We furthermore have the facilities and funding to complete the work. However, all labs have been shut down due to the COVID-19 pandemic. Data collections are ready to be initiated as soon as human research resumes at the university. Given uncertainty around when labs will be reopened, we offer a proposed resubmission window from November 15th, 2020 to May 15th, 2021.

All authors agree to share the raw data, any digital study materials, including experimental and analysis code, and laboratory log for all published results. We will also register the protocol on the Open Science Framework regardless of our acceptance here. We expect other labs and research groups will have a strong interest in trying to replicate the results of this work, as the topic should be of interest to neuroscientists engaged in motor learning, locomotion, and clinical research. Thus, our steps towards transparency in all aspects of this research project should facilitate others’ efforts in this direction. Lastly, if we later withdraw this paper, we agree to eNeuro publishing a short summary of the pre-registered study under the Withdrawn Registration section.

We look forward to your assessment.

Sincerely,

Jonathan Wood, Susanne Morton and Hyosub Kim