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Gradual training reduces practice difficulty while preserving motor learning of a novel locomotor task

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ABSTRACT

Motor learning strategies that increase practice difficulty and the size of movement errors are thought to facilitate motor learning. In contrast to this, gradual training minimizes movement errors and reduces practice difficulty by incrementally introducing task requirements, yet remains as effective as sudden training and its large movement errors for learning novel reaching tasks. While attractive as a locomotor rehabilitation strategy, it remains unknown whether the efficacy of gradual training extends to learning locomotor tasks and their unique requirements. The influence of gradual vs. sudden training on learning a locomotor task, asymmetric split belt treadmill walking, was examined by assessing whole body sagittal plane kinematics during 24 hour retention and transfer performance following either gradual or sudden training. Despite less difficult and less specific practice for the gradual cohort on day 1, gradual training resulted in equivalent motor learning of the novel locomotor task as sudden training when assessed by retention and transfer a day later. This suggests that large movement errors and increased practice difficulty may not be necessary for learning novel locomotor tasks. Further, gradual training may present a viable locomotor rehabilitation strategy avoiding large movement errors that could limit or impair improvements in locomotor performance.

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1. Introduction

There exists an abundance of motor learning strategies (Schmidt & Lee, 2005) that can be used to make practice more difficult. Such an approach to training has been consistently shown to improve motor learning despite decrements in initial performance (Christina & Bjork, 1991; Schmidt & Bjork, 1992; Schmidt & Lee, 2005). Practice difficulty can also be manipulated by controlling the rate at which the task requirements of a motor skill are introduced during training. Specifically, practice difficulty can be increased by using a sudden training strategy whereby task requirements are abruptly introduced and then maintained throughout practice, an approach which results in large movement errors (Criscimagna-Hemminger, Bastian, & Shadmehr, 2010). Alternatively, practice difficulty can be reduced by using a gradual training strategy which incrementally introduces task requirements over the course of a practice session, resulting in small movement errors which often go unnoticed by the learner (Criscimagna-Hemminger et al., 2010).

The detection of large movement errors by the cerebellum (Morton & Bastian, 2006; Shadmehr, Smith, & Krakauer, 2010), and subsequent correction by the motor system is thought to be critical to sensorimotor motor learning as it drives the adaptation of movement strategies and the acquisition of motor skills (Lisberger, 1988; Rumelhart, Hinton, & Williams, 1986; Tseng, Diedrichsen, Krakauer, Shadmehr, & Bastian, 2007) by updating an internal model of the interaction between the limb and the environment (Wolpert & Ghahramani, 2000). Thus, the more challenging sudden training and its large movement errors has been proposed as a means to increase practice difficulty and enhance motor learning by cueing the nervous system to make movement corrections in response to large movement errors (Reisman, Bastian, & Morton, 2010). However, a number of studies in which participants practiced visually distorted or physically perturbed reaching tasks have demonstrated that upon removal of the perturbation, individuals who received gradual training exhibited a slower rate of decay of the adapted reaching pattern, taking longer to reestablish unperturbed reaching movements; an indication that these individuals adapted to the novel reaching tasks more thoroughly than those who received sudden training (Buch, Young, & Contreras-Vidal, 2003; Criscimagna-Hemminger et al., 2010; Huang & Shadmehr, 2009; Kagerer, Contreras-Vidal, & Stelmach, 1997; Taylor, Wojaczynski, & Ivry, 2011).

Beyond short term adaptive responses, novel reaching skills practiced using gradual training are retained as well or better than those using sudden training (Klassen, Tong, & Flanagan, 2005), and appear to generalize to conditions that differ from those of original practice better than after sudden training (Malfait & Ostry, 2004). This suggests that gradual rather than sudden training results in superior motor learning. Thus it would appear that sudden training and large movement errors may not be necessary for motor learning. Therefore, gradual training may be an effective rehabilitation strategy for retraining populations where large movement errors could present substantial challenges, altering what movement strategies are selected to perform the task and how well they are learned. Additionally, not all individuals are responsive to sudden training (Criscimagna-Hemminger et al., 2010; Musselman, Patrick, Vasudevan, Bastian, & Yang, 2011; Reisman et al., 2010).

To date only one study has examined the influence of gradual versus sudden training on locomotor tasks (Torres-Oviedo & Bastian, 2012). In this study of short term adaptations, gradual training resulted in a slower rate of decay of an adapted locomotor pattern, while sudden training induced greater initial adaptation to the novel locomotor task (Torres-Oviedo & Bastian, 2012). It remains unknown whether the efficacy of gradual training demonstrated for the delayed retention and transfer of novel upper extremity reaching tasks (Klassen et al., 2005; Malfait & Ostry, 2004) generalizes to the delayed retention and transfer of locomotor skills and their unique requirements. A better understanding of whether and how gradual versus sudden training influences the acquisition of locomotor skills may be particularly important to locomotor rehabilitation, especially considering the emergence of powered prosthetic and exoskeleton technology. Given the rapid rate of technological advancement in the field of prosthetics and orthotics (Grill, 2007), the development of appropriate training strategies will be essential to ensure the most effective and widespread application of these devices among individuals with locomotor impairments.

The objective of this study was to determine whether gradual versus sudden training influenced how well a novel locomotor task was learned. This was accomplished by examining whole body sagittal plane kinematics during training and 24 hour retention or transfer performance of a novel