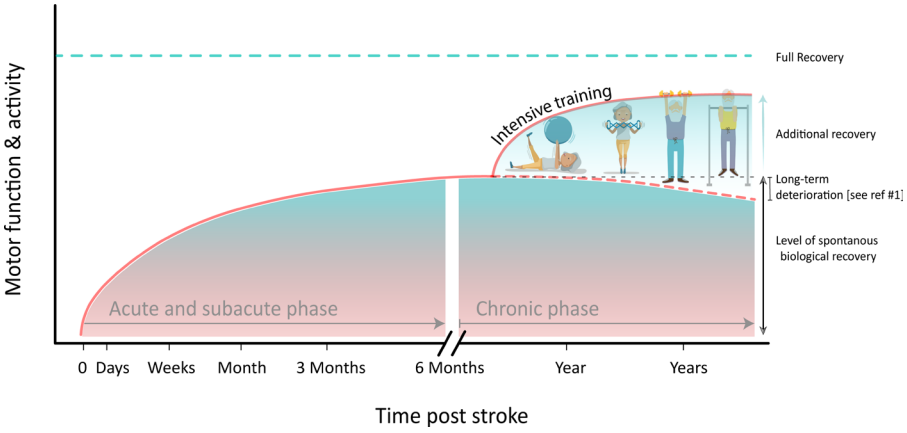

Figure 1 'Much more is better' seems to be the take home message of this aspirational study. Intensive and high-dose behavioural training at the chronic stages poststroke is feasible and could lead to clinically meaningful changes in both impairment and function back towards and beyond the maximum achieved recovery that has been reported until now.

The dose and intensity matter for chronic stroke

Stroke is one of the most common causes of physical disability worldwide, and the majority of patients experience impairment of movement. Each year, approximately five million new people are left permanently disabled by stroke. Long-term reduction of impairment and restoring of function are of critical challenges. To date, the general consensus remains that current levels of rehabilitative training in chronic stroke result in minimal improvement, and are ineffective at enhancing recovery from motor impairment beyond what is achieved in the acute poststroke stage (eg, from spontaneous biological recovery). Furthermore, this recovery of functional and motor outcomes has even been shown to gradually deteriorate from the level of recovery achieved at 6 months poststroke to that at 2 months by 5 years poststroke,[1] leaving stroke victims to suffer the remaining handicaps. In addition, it is argued that improvement following task-specific training in stroke does not necessarily stem from improvement in general movement quality. Recent study by Ward *et al*, 2019[2] addressed these questions and provided compelling evidence that intensive and high-dose behavioural training in the chronic poststroke stage could lead to clinically meaningful changes in both impairment and function, showing that effects from their rehabilitation programme lasted, or even improved, for at least 6 months after training.

The authors built on convergence of recent evidences that have suggested the crucial importance of time spent in training (ie, dose) and amount of activity (ie, intensity) in boosting the generalised gains past those achieved by spontaneous biological recovery, and past those reported in studies implementing standard low-dose and/or low-intensity rehabilitation protocols. In the investigated programme, several key strategies were considered in order to maximise gains in motor control within activities of daily living, including implementation of a personalised, adaptive and intensive training programme of motor tasks with the focus on movement quality, as well as implementation of coaching, which was used throughout to embed skills and knowledge into individual activities of daily living. Interestingly, the gains achieved in this 90-hour programme are comparable in magnitude to a previous clinical trial that investigated the effect of 300 hours of upper limb rehabilitation in a similar but much smaller population of patients.[3]

The findings of this study break through the ceiling of the current standing in poststroke recovery, in which little improvement due to current standard rehabilitation protocols, after the window of the spontaneous biological recovery process, has been reported. Alternatively, it suggests that the recovery boundary is subject to change if enough practice is used in the therapeutic paradigm (figure 1); and a major factor in the lack of true recovery in current rehabilitation protocols is because the implemented dose and intensity were too low. In addition, the quite large improvement on global scales of activities of daily living indicated that improvement was not restricted to task performance and completion, but rather to broad improvement in movement. Also supporting this idea is the fact that outcomes continued to improve even 6 months after cessation of training, possibly suggesting the involvement of positive feedback of simply using the affected hand in activities of daily living after training, as well as the importance of education and focus on self-efficacy which Ward *et al*[2] associated with the continued improvement. This suggests that the recovery boost from the programme could, at least in part, be leading patients with stroke back towards (and beyond) the maximum level that they achieved early on after stroke.

Nevertheless, although the study presents intriguing and promising results with a new approach that should be considered in the clinics and rehab centres, we must admit that it was hard to draw all details necessary to design the optimal protocol. For example, it was not clear how the personalised protocol was implemented or how the transition from passive to active, and from assisted to unassisted, functional tasks should be scheduled. In addition, nuances like motivation, self-efficacy and confidence seemed to play key roles in the proposed regime, yet they were neither reported nor controlled. In fact, such factors might be related to the 'enriched environment' approach discussed recently by Krakauer and Cortés 2018[4], and used previously in an animal model of stroke.[5] Although the precise mechanisms of enrichment are not fully understood, they likely engage motivational effects driven by reward-related circuits.[5]

There is an opportunity to further disentangle the minimal/optimal threshold of intensity and dose that patients, at the individual level, must exceed before a meaningful effect on outcomes is observed. How do motivation and enriched environment affect

recovery over different timescales after stroke? What biomarkers of poststroke plasticity mechanisms are needed to account for the variability across patients in terms of who and when to train? Designing randomised, multicentre and longitudinal clinical trials outlining the precise strategies, in conjunction with basic clinical neuroscience experiments, is an important endeavour to follow-up on the results by Ward *et al*.[2]

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