Robots for stroke rehabilitation: not all that glitters is gold

In today's high-tech world, we are witnessing an exponential growth of advanced technology used to support both inpatient and outpatient rehabilitation (Masiero et al., 2014).
Accordingly, it is now possible to carry out rehabilitation sessions that are, at the same time, intensive, task-specific, motivating and capable of providing adequate feedback to drive plasticity-dependent recovery (Morone et al., 2017, 2012).
The two main developments characterizing the field of neurorehabilitation over past two decades have been the advance of technologies and the growing realization that the brain is far more plastic in structure and function than was previously believed (Kolb et al., 2014).
Unfortunately, intention and action cognitive-motor mechanisms do not always coincide with normal physiology in subjects affected by stroke or other CNS damage. A rehabilitation process is a medical intervention, aiming to promote motor-cognitive functional recovery through modification of neural networks, or their functional substitution. In this context, brain plasticity helps to promote recovery, but could potentially also lead to maladaptive network change, not geared at motor recovery, depending on genetic or epigenetic mechanisms, as well as neurorehabilitation choices (drugs, neuromodulation, exercises promoted with or without technologies and robots) and subjects' psychological characteristics (Lotze et al., 2019; Bragoni et al., 2013). Just as neurorehabilitation techniques are not adaptable to every type of pathological and functional condition, so technological devices and robots supporting therapeutic exercises should not be the same for all conditions. For example, robots and technologies developed for motor substitution should be different from those utilized for rehabilitation that aims to boost motor recovery. However, it is known that, for design, construction and marketing reasons, robot manufacturers try to target a broad spectrum of functions and pathological conditions, and sometimes even disciplines (medicine, military, industry). While this may be acceptable from a commercial point of view, it is not acceptable from a clinical one. Although we are increasingly using robots in clinical neurorehabilitation, on the basis of some post-commercialization evidence of their efficacy, in some ways robots continue to represent an eternal promise. Certainly, their implementation got off to a difficult start on account of excessively high expectations and the lack of adequate information given to end-users. As a result, the past two decades have seen clinicians divided into those who are enthusiastic about robot therapy and those who are more pessimistic (Iosa et al., 2016). These first 20 years of robotic rehabilitation will go down in history as the ones that allowed the creation of a relationship between robots and end-users (patients, physicians and physiotherapists), laying the foundations necessary to arrive at the production and commercialization of specific and cost-effective robots for rehabilitation. If robots are better to meet clinical needs, the next 20 years will need to see a series of improvements, as proposed in the Table below.

Main advantages Robotic therapy is able to:	**Hypothesis on the main areas to be developed Robotic therapy needs to:**
• increase efficacy in regaining certain abilities (i.e. reaching and grasping, balance and walking), particularly in subacute and severe subjects (Mehrholz et al., 2018, 2017). • reinforce some aspects of individualized rehabilitation projects, e.g. reduce spasticity (Gandolfi et al., 2019), improve postural lateralization, improve cordiorespiratory efficiency, increase bone mineralization/improve body composition • improve cognitive-motor aspects through video-visual augmented feedback (e.g. attention, memory, visuomotor functions) (Buchwald et al., 2018; Choi et al., 2016) • provide mobility in upright position (e.g. motor substitution for paraplegic patients) (Guanziroli et al., 2018) • explore some aspects of motor recovery and motor plasticity (Vahdat et al., 2019) • assess functional recovery during the rehabilitation process (McKenzie et al., 2017)	• improve sensory-motor interaction between robot and subject (not only force) • provide better clinical indications and contextualization of robot use during rehabilitation (who, what dose, with what frequency) • integrate physiological signals related to motor intention and action (EEG modification, EMG modification) (Wang et al., 2018; Nam et al., 2017) • enrich sensory-perceptual systems not only as a bottom-up process but also with cognitive top-down contamination/integration • take into account robot embodiment • take into account psychological considerations • take into account neuro-robotic ethics considerations • improve, through artificial intelligence, robots used for rehabilitation • increase online information available to therapists based on patient performances during robotic training (e.g. vital and neurovegetative signs, attention paid, workload, motivation)

In conclusion, robotics today is not only the prerogative of research and university hospitals; indeed it is even spreading to smaller neurorehabilitation hospitals. Nevertheless, there are still many areas needing to be addressed, including clinical indications and the reimbursement of robotic therapy by healthcare systems and insurance companies. There is therefore an urgent need for a clinical consensus conference able to provide evidence and indications to support, guide and improve the use of robotic rehabilitation in different neurological conditions. The results obtained by the current robots and the lessons learned from the past should help engineers and clinicians not only in the development of future robots, but also in the construction of a future for robots in neurorehabilitation, avoiding pessimism but nevertheless remembering that not all that glitters is gold.

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