Striking the Balance: Embracing Technology While Upholding Humanistic Principles in Neurorehabilitation

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Hugo Ardaillon
Hospices Civils de Lyon (Centre Hospitalier Universitaire de Lyon)

Shams Ribault
Hospices Civils de Lyon (Centre Hospitalier Universitaire de Lyon)

Laure Pisella
French Institute of Health and Medical Research

Karen T Reilly
French National Centre for Scientific Research

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Striking the Balance: Embracing Technology While Upholding Humanistic Principles in Neurorehabilitation

Hugo Ardaillon, MD[1,2], Shams Ribault, MD[1,2,3], Caroline Herault, MD[1], Laure Pisella, PhD[2], Nicolas Lechopier, PhD[2,4], Karen T. Reilly, PhD[2*], and Gilles Rode, MD, PhD[1,2*]

Abstract

Background. The rapid advancement of technology-focused strategies in neurorehabilitation has brought optimism to individuals with neurological disorders, caregivers, and physicians while reshaping medical practice and training. *Objectives.* We critically examine the implications of technology in neurorehabilitation, drawing on discussions from the 2021 and 2024 World Congress for NeuroRehabilitation. While acknowledging the value of technology, it highlights inherent limitations and ethical concerns, particularly regarding the potential overshadowing of humanistic approaches. The integration of technologies such as robotics, artificial intelligence, neuromodulation, and brain-computer interfaces enriches neurorehabilitation by offering interdisciplinary solutions. However, ethical considerations arise regarding the balance between compensation for deficits, accessibility of technologies, and their alignment with fundamental principles of care. Additionally, the pitfalls of relying solely on neuroimaging data are discussed, stressing the necessity for a more comprehensive understanding of individual variability and clinical skills in rehabilitation. *Results.* From a clinical perspective, the article advocates for realistic solutions that prioritize individual needs, quality of life, and social inclusion over technological allure. It underscores the importance of modesty and honesty in responding to expectations while emphasizing the uniqueness of each individual's experience. Moreover, it argues for the preservation of human-centric approaches alongside technological advancements, recognizing the invaluable role of clinical observation and human interaction in rehabilitation. *Conclusion.* Ultimately, the article calls for a balanced attitude that integrates both scientific and humanistic perspectives in neurorehabilitation. It highlights the symbiotic relationship between the sciences and humanities, advocating for philosophical questioning to guide the ethical implementation of new technologies and foster interdisciplinary dialogue.

Keywords

neurological rehabilitation, biomedical enhancement, biomedical technology, medical informatics, neurosciences, anthropology, education, sociology and social phenomena category, social sciences, humanities, philosophy

Dear Editor,

The ever-growing development of new high-tech applications and technology-focused approaches in the field of neurorehabilitation has not only bought hope to individuals with neurological disorders or injuries, their caregivers and physicians, but has also reshaped medical practice and training. These topics were the subject of numerous papers and symposia during the 2021 congress held in Vienna,[1] as well as the latest, 13th World Congress for NeuroRehabilitation (WCNR 2024) in Vancouver, where we observed an emphasis within the community on sophisticated technology, including robotic devices and the visualization, recording, and analysis of brain activity. While these approaches merit a genuine interest and enthusiasm, technology-based methods have several inherent limitations, and their use in rehabilitation raises significant concerns, one of which is their tendency to put the technology at center stage, overshadowing (or even eclipsing) the person. While it is important to integrate technology and innovation into rehabilitation, the complexity of each individual's situation, including their history, current environment, and future objectives to improve their quality of life, means that the place occupied by technology should be equal to that occupied by more holistic and humanistic approaches drawn from the humanities and social sciences. Friction can arise when actions are guided by different approaches, such as technology-centered or human-centered, but it is crucial to avoid opposing technological advancements and humanistic values. The ethical guidelines outlining neurorehabilitation practice should include seamless integration of technology into a humanistic framework. By recognizing their complementarity, we can harness technology potential while upholding humanistic values, fostering more inclusive approaches in neurorehabilitation.

Neurorehabilitation, like other forms of rehabilitation for long-term conditions such as cardiac and pulmonary disease, places sensorimotor experience, psychological, behavioral, and social factors at its center, delving exploring the essence of what it means to be human. Neurorehabilitation is therefore inextricably intertwined with an individual's sense of self, identity, and subjectivity. The stakes extend well beyond mere technical health concerns, meaning that an imbalance overly favoring technology could jeopardize rehabilitation outcomes, the quality of the care received by each person, and their quality of life.

Opportunities for Technological Advancements in Neurorehabilitation

Technology is the strategic application of scientific or conceptual knowledge to achieve a specific goal. It encompasses a diverse range of mechanical tools, digital applications, and advanced methodologies, all designed to improve patient outcomes and facilitate targeted medical interventions. The presence of new technologies (eg, robotics, artificial intelligence [AI], methods for assessing cerebral activity, neuromodulation, neurobiofeedback, and brain-computer interfaces) greatly enriches neurorehabilitation, introducing a truly interdisciplinary approach. Technology is useful in neurorehabilitation and other medical contexts, providing testable models (the groundbreaking work of Alan Turing laid down the foundations for modern cognitive neuroscience[2]) and practical tools to improve function, accessibility and inclusion. For example, computational neuroscience methods and models are invaluable for understanding the mechanisms of cerebral plasticity after injury (artificial neural networks, functional, or object vicariance). Similarly, AI tools are increasingly being used to provide personalized care based on an individual's characteristics, for example in selecting the post-stroke rehabilitation program likely to produce optimal functional outcomes. In the present day, informatics continues to serve as a valuable model for understanding the mechanisms of cerebral plasticity following injury, utilizing tools such as artificial neural networks, functional vicariance, or object vicariance.[3] Furthermore, employing AI as a tool can aid in selecting the most suitable rehabilitation program tailored to an individual's personalized characteristics, as seen in stroke recovery scenario.[4] Additionally, emerging blood biomarkers are becoming accessible indicators of neuroplastic processes, brain function, and recovery mechanisms. These biomarkers can provide a more accessible and simpler alternative to advanced imaging techniques for healthcare providers around the globe.[5,6]

Challenges and Ethical Considerations

The first issue at hand is to determine whether the actions of such devices focus on recovery, compensation for deficits, or both. Perhaps the most striking example of technology in neurorehabilitation, one that consistently receives overwhelming media coverage, involves brain-computer interfaces and their promise of compensating for language deficits by restoring communication to heavily disabled individuals using methods like text editing and speech synthesis.[7] Another promising technology involving brain-computer interfaces is the digital bridge: a brain-spine interface that holds the promise of bypassing a spinal cord injury to restore walking.[8] Exoskeleton-assisted rehabilitation is also increasingly offered to individuals with mobility impairments, either as part of a recovery program or for compensation purposes. Only available in a small number of rehabilitation centers with the financial means to acquire these expensive robots, it involves wearing a robotic device

[1]Service de Médecine Physique et Réadaptation, Plateforme Mouvement et Handicap, Hôpital Henry Gabrielle, Hospices Civils de Lyon, Saint-Genis-Laval, France
[2]Université de Lyon, Université Lyon 1, INSERM U1028; CNRS UMR5292; Lyon Neuroscience Research Center, Trajectoires Team, Lyon, France
[3]Pathophysiology and Genetics of Neuron and Muscle, CNRS UMR 5261, INSERM U1315, Faculté de Médecine, Université Lyon 1, Lyon, France
[4]Sciences et Société ; Historicité, Éducation et Pratiques [S2HEP], Lyon, France

*These authors contributed equally to this work.

Corresponding Authors:
Hugo Ardaillon, MD, Service de Médecine Physique et Réadaptation, Plateforme Mouvement et Handicap, Hôpital Henry Gabrielle, Hospices Civils de Lyon, 20 Route de Vourles, Saint-Genis-Laval, Auvergne-Rhône-Alpes 69230, France.
Email: hugo.ardaillon@chu-lyon.fr

Gilles Rode, MD, PhD, Service de Médecine Physique et Réadaptation, Plateforme Mouvement et Handicap, Hôpital Henry Gabrielle, Hospices Civils de Lyon, 20 Route de Vourles, Saint-Genis-Laval, Auvergne-Rhône-Alpes 69230, France.
Email: gilles.rode@chu-lyon.fr

that assists or enhances the physical capabilities of the wearer and is able to adjust to their specific needs and capabilities.[9] Additionally, despite the fact that manufacturing costs for exoskeletons and prosthetics are rapidly dropping, their effectiveness and fair accessibility is not yet guaranteed. For example, despite the significant financial investment in myoelectric prostheses, some individuals find them impractical due to design flaws (eg, heaviness) exacerbating mobility challenges rather than mitigating them. This underscores the necessity of considering not only the cost but also the usability and practicality of use. Clinical studies must determine the circumstances under which technology can improve health and quality of life,[10] and new technologies should undergo rigorous evaluation for safety, efficacy, and cost. Where cost is not only financial, but includes acceptability, usability, and comparison with lower-cost alternatives in terms of long-term health outcomes and quality of life. For example, the use of invasive devices for cerebral modulation should be decided with great caution. As stated by Surjo R. Soekadar at the last WCNR,[10] most cerebral implants are developed by private, for-profit, start-ups which are vulnerable to bankruptcy. Thus, individuals sometimes find themselves with malfunctioning implants or no ongoing technical maintenance[11,12] (sustainability principle). Furthermore, the lesion-related effects of invasive technologies, including adverse events like hemorrhage or infection, can be harmful and permanent (even after the removal of implants). In many instances, the use of non-invasive devices provides a safer alternative that is equally effective. A range of other criteria should be taken into account when making clinical decisions: the possibility of control of use by the person (autonomic principle[13]), the value of use (risk-to-benefit ratio, or beneficence and non-maleficence principles[13]), and whether the technology promotes fairness or inadvertently widens social inequalities for low-income individuals or in low-income countries (equity or justice principle[13]). Furthermore, we should assess whether the technology aligns with or challenges our fundamental understanding of humanity (authenticity principle). Voicing their concerns about cost efficiency, in 2022 Putrino and Krakauer stated that '*there is a real danger of using technology on the grounds of either cost saving or perceived gains in efficiency but as a consequence actually decrease the quality of care by either reducing in-person interaction or removing human beings from the loop altogether*'.[14]

Rehabilitation therapists play a crucial role in utilizing emerging rehabilitation technologies and are trained to place patients and their individual goals at the center of the rehabilitation process. They typically seek practical and efficient tools that benefit their patient, and assist them in their daily practice. They often find cumbersome and even counterproductive, devices like exoskeletons which require extensive setup time and necessitate the presence of multiple therapists. Such tools not only consume valuable human resources but also detract from direct patient care. Therefore, the integration of emerging technologies should prioritize simplicity and usability to optimize therapists' time and enhance patient outcomes.

The Pitfalls of the Brain

Neurorehabilitation research stands to gain significantly from a more comprehensive understanding of brain physiology and pathology, leveraging potential advancements in cerebral imaging. A major problem with this approach, however, is that functional imaging or electrophysiological results are often presented in scientific publications as statistical means derived from a population. Information about intra- and inter-individual variability is commonly treated as noise rather than an informative source of information that could be used to inform the design of patient-tailored interventions. While scientific progress is often based on sample populations (for statistical power), medical practice operates at the level of the individual, requiring a different perspective from that used in most current biomedical research. This disparity exemplifies the conflict between generalization and contextualization within medicine, both as a science and as a practice.

By integrating behavioral investigations with state-of-the-art imaging techniques, it is possible to examine changes following a neurological event at an individual level. Both deficits and productive symptoms can be associated with alterations in brain structure and function, as can the nature and progression of recovery. Thus, these types of studies can make invaluable contributions to our understanding of recovery and plasticity phenomena in neurorehabilitation.[15] However, there is a risk that training physicians in this approach may inadvertently overemphasize the technology and use of state-of-the-art methods, potentially overshadowing the significance of neurological clinical skills, which form the cornerstone of reasoning in neurorehabilitation.[16] Once again, it is a question of balance, and clinical skills should be accorded equal importance alongside technology in both clinical practice and scientific investigation. Unfortunately, the bias toward the allure of "seeing an image of the brain" in a scientific paper is documented, and one must exercise caution in the presence of beautiful, captivating images, as they can be accompanied by unfounded conclusions and unconvincing or overinterpreted data.[17] In light of epistemological skepticism, it is important to recognize that while functional imaging provides meaningful information related to brain function, metabolism, and morphology, it involves statistical operations and consequently, the final results are often highly dependent on the chosen method.[18]

The construction of new scientific paradigms could benefit from approaches used in the humanities which foster both flexibility and rigor while exploring complex phenomena. Disciplines like philosophy, ethics, and anthropology offer perspectives that transcend narrow techno-centric viewpoints and hypothetical-deductive approaches, by using qualitative techniques that provide access to information about phenomena that cannot be directly observed or reduced to experimentally reproducible setups. One application of this in the field of neurorehabilitation could be to embed qualitative research into quantitative approaches as quantification enables conclusions about statistical significance but can sometimes be of limited clinical significance. Another approach is to adopt a "neuroskeptic approach" (an epistemological stance questioning the validity, utility, or safety of neuroscientific knowledge),[19] which could lead to a more balanced perspective on commonly accepted, "neuro-centered" understandings of our brains and ourselves, thereby fostering "fruitful skepticism."[20]

The Clinical Perspective: A Path to Realistic Solutions

The time it takes to transfer high quality scientific knowledge and innovation into care pathways is typically in the order of years, even decades.[21] This slow pace of knowledge transfer is often criticized, but far from being a loss of time it enables knowledge translation from bench-to-bedside to occur in a safe, appropriate manner allowing for the evaluation of efficacy and safety, but most importantly acceptability by individuals directly concerned. The allure of a highly technological object (economy of promise) should be tempered by considerations related to accessibility, applicability, and whether the object or technological solution tackles a genuine need of those it is intended to serve. It is crucial to inquire whether investments, both in terms of finances and time, are directed toward addressing the real-world, everyday issues that are of utmost concern to these individuals.

Despite the potential benefits promised by the increasing presence of technology in neurorehabilitation, physicians and researchers are unable to predict future advancements and, the quotidian reality of being responsible for improving the situation of individuals in need of care dictates that most decisions be made on a case-by-case basis. Moreover, individuals typically prioritize the improvement of functions that cause the greatest distress or disability. Surprisingly, most individuals with spinal cord injury prioritize restoration of bowel function over walking.[22] However, there is a noticeable imbalance in efforts to restore these functions in terms of allocation of technological resources and efforts, and future research into technological applications cannot ignore this. It is essential to establish a balance between quality of life and social inclusion and restoration of higher-level functions. This will require medical professionals responding to the hopes of individuals and caregivers regarding the potential of scientific advancements with modesty and honesty, basing their responses on the best available knowledge (reality principle). Questions regarding the accessibility of clinical applications within one's lifespan and the legitimacy of discontinuing a rehabilitation program while awaiting a function-restoring device warrant careful consideration. Situating expectations within a realistic temporal context can provide much sought-after answers which cultivate hope without succumbing to hype.

The study of an individual's behavior is at the very heart of neurorehabilitation. Physicians must consider a person's intentionality, self-awareness, narrative self,[23] and subjectivity, as each individual stands within the uniqueness of their own experience and environment. The danger represented by state-of-the-art neurotechnology is its potential to overshadow or even erase the person in favor of the technology itself. Neurotechnology should serve as a tool to investigate practical questions and should not diminish the individual being studied. The use of technologically complex tools can lead to the perception that the subject of study is also complex. Individuals seeking care for rehabilitation are indeed complicated "objects of study," but it would be a shame to disregard low-tech assessment methods and interventions. While clinical observation might be considered a low-tech skill by some, it relies on a highly complex tool (the human). Thorough and attentive observation by skilled professionals yields a wealth of information. For example, in the case of individuals with disorders of consciousness, some authors suggest that the observation of behavior by experienced professionals (ie, nurse teams) yields comparable information to that gained from neuropsychological or electrophysiological assessments.[24-26] Furthermore, while clinical examination by a human provides highly reliable information for diagnosis and care management, it also facilitates the establishment of meaningful relationships between individuals, an essential element for recovery that is absent when the examination is performed by a robot.

Claude Bernard, a French physician and physiologist credited with discovering experimental medicine, stated in his acceptance speech to the French Academy in 1869: "*The manifestations of the intelligence are not an exception to the other functions of life; there is no contradiction between the physiological and metaphysical sciences; they only approach the same problem of the intellectual human from opposite sides. [. . .] two orders of sciences have been distinguished: the first springs from the mind and goes down to the phenomenon of nature, the other springs from the observation of nature only to go up to the mind. Their starting points are different, but their goal is the same: the search* *and the discovery of the truth. It is only the darkness of our ignorance that makes us assume limits between these two orders of sciences.*"[27]

In conclusion, the challenge posed by neurotechnology for neurorehabilitation could be expressed as the necessity to strike a balance, to find the equilibrium point, or a *middle ground*, between the sciences and the humanities, which should closely align with the patients' expectations. This idea of a *middle ground* echoes the concept developed by the philosopher-mathematician Blaise Pascal (1623-1662).[28] This is particularly pertinent in an environment where the boundaries between the humanities and science are becoming increasingly permeable and blending, as both disciplines integrate each other's methodologies into their respective frameworks. Debates between the humanities and the sciences mutually enrich both fields, and analyzing new technologies through the lens of philosophical questioning fosters a productive friction conducive to the emergence of new knowledge.[29] To achieve a balance between technology and humanism in neurorehabilitation, a concrete action plan should therefore integrate humanistic principles into the design and implementation of new technologies, provide comprehensive training for therapists and clinicians on both technological and humanistic approaches, encourage the conduct of multidisciplinary research that combines technological advancements with insights from the humanities, ensure equitable access to technological innovations, and engage patients and caregivers in the development and evaluation of new technologies.

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ORCID iDs

Hugo Ardaillon https://orcid.org/0000-0002-4113-2427

Shams Ribault https://orcid.org/0000-0001-5988-6684

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