

Bridging the High-Tech Divide: Why Cognitive Care Must Remain Human-Centered

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Aging of the global population leads to the emergence of the increase in neurodegenerative disorders and cognitive dysfunction with dementia expected to increase from 57.4 million cases in 2019 to 152.8 million by 2050 with the disproportionate impact on developing nations ^{1,2}. Mild Cognitive Impairment (MCI) affects 13-17% of adults older than 50, along with cognitive deficits due to stroke, Traumatic Brain Injury (TBI), and Attention-Deficit/Hyperactivity Disorder (ADHD). Cognitive impairments reduce patient functioning and pose significant physical, psychological, and economic burden on informal caregivers ¹⁻⁴. For example, the socioeconomic cost of dementia was estimated as \$250 billion in 2020 in China, where family members are under significant psychological pressure because of a lack of nationwide assistance ¹.

Neuro-rehabilitation is increasingly relying on advanced technological innovations, including Artificial Intelligence (AI) for health tracking, digital biomarkers for disease detection, and VR for cognitive training ^{5,6}. New and advanced technologies such as neuro-imaging and "Cognitive-Physiological Digital Twins" (CPDTs) that represent digital replica of the physiological states of a patient became popular in clinical setting ⁷. However, rapid development of technologies such as digital health might pose additional barriers including the difficulty to navigate through information and risks of overloading the patient and reducing his/her participation ^{2,5}. Thus, technology should enhance clinicians' and caregivers' skills, not replace human empathy and complex clinical reasoning necessary for successful treatment ².

Use of AI in the early detection of cognitive dysfunction shows great promise. Machine learning can detect physiological changes not perceptible to humans ⁸. For example, automated speech and language analysis achieves about 80% accuracy in differentiation between MCI and healthy control with use of the biomarkers such as low semantic coherence and high number of pauses ^{8,9}. Wearable sensors used in testing such as "Timed Up and Go" can achieve 97.75% accuracy ^{8,10}. Despite usefulness, these AI systems often work as "black box" unable to understand the context of emotions, nonverbal communication, and social situation experienced by a patient ^{11,12}. They may ignore important factor – subjective well-being of a patient necessary to achieve good outcomes without any human control ^{11,13}.

Immersive VR revolutionized neuro-rehabilitation for stroke and TBI survivors through allowing patients to learn how to perform everyday activities such as preparing toast or going to a grocery store in a safe environment in 3D games such as VIRTUE ^{14,15}. This technology increases engagement of patients and fosters self-efficacy ¹⁶. However, cybersickness, fatigue, limited transfer to real world, and lack of interactive communication still remains major issues ^{14,17}. Virtual assistants cannot substitute the important component of therapy known as therapeutic alliance – the relationship between therapist and patient ^{15,17}.

Neuromodulation techniques, such as Deep Brain Stimulation (DBS) targeting specific neural networks can help improve memory and executive functions in some patients with long-lasting effects ¹². Such techniques bring a lot of neuroethical issues, including the question of protection of personal identity and story of a patient ¹². Human identity in combination with AI and issue of informed consent in patient with limited consciousness require close ethical scrutiny ¹². Thus, mental privacy of a patient and restoration of her/his agency, not improvement of performance of machines, is the important task ¹².

The development of cognitive healthcare in the future will rely on the "human-in-the-loop" approach whereby the role of AI and CPDTs will be to assist but not replace the clinician ⁷. Multimodal data integration into CPDTs may enable simulating the course of patients' diseases, facilitating clinical decision-making ⁷. Combined with DTx, these tools must ensure the expansion of the scope of medical activities into patients' houses and real-time coaching to reduce the burden of care ^{2,6,7}. It calls for the transition towards "human-centered" AI, which acknowledges patients as stakeholders and subjects who have their data-related rights and interests ⁷.

To achieve it, coordinated actions should be taken: the developers and engineers of AI technologies need to implement participatory co-design with the help of clinicians and patients, including privacy safeguards at an early stage of development ^{2,7}; the healthcare providers need to address the "digital health gap" by implementing the necessary digital literacy and care provider training ^{2,6}; and the policy-makers and regulators need to set up harmonized global standards and guidelines to avoid the risks of algorithmic bias before the deployment of neurotechnology ^{6,18,19}. In the end, the neurotechnology should facilitate the connection between the patient and the physician, not automate it ².

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