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DISCOVERY
SCIENTIFIC SOCIETY

From Algorithms to Patient Care: Artificial Intelligence in Neurological Rehabilitation – A Review

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ABSTRACT

Stroke, traumatic brain injury, and multiple sclerosis are neurological disorders that cause a lot of long-term disability and put a lot of strain on society and the economy. Rehabilitation is necessary for regaining functionality. But standard practices often don't allow for much personalization, intensity, or accessibility. Artificial intelligence (AI) and machine learning (ML) have recently emerged as promising instruments for enhancing neurological rehabilitation by facilitating more accurate evaluation, tailored therapy planning, and continuous monitoring of patient progress. The goal of this review is to give an overview of how AI is currently being used in neurological rehabilitation. It includes things like tele-rehabilitation, brain-computer interfaces, robotic-assisted therapy, and motor recovery after a stroke. The research demonstrates that AI-driven interventions can enhance therapy intensity, forecast recovery outcomes, and utilize objective assessments of motor and cognitive function. Telerehabilitation platforms make it easier to get care outside of the clinic. Robotic systems and AI-enhanced virtual environments, on the other hand, allow patients to train in ways customized to their needs. Even with these changes, there are still problems with algorithm transparency, data privacy, and guaranteeing fair access for everyone, including in clinical practice. Our goal in this review is to demonstrate how AI and ML can revolutionize neurological rehabilitation by providing scalable, individualized approaches that improve clinical results. Long-lasting effectiveness, standardization procedures, and useful workflow integration should be the main topics of future research.

Keywords: artificial intelligence, machine learning, neurological rehabilitation, stroke recovery, robotic therapy, brain-computer interface, tele-rehabilitation

1. INTRODUCTION

Neurological disorders, including stroke, traumatic brain injury, multiple sclerosis, and disorders of consciousness, are a major global health challenge. They often lead to long-term disability and place a significant burden on both individuals and healthcare systems. According to estimates, neurological diseases caused more than

276 million disability-adjusted life years (DALYs) and about 9 million deaths around the world in 2016. These numbers are likely to increase, with estimates suggesting they will rise by 50% by 2040 (Lee & Laureys, 2024).

Rehabilitation is important because it helps improve quality of life, supports recovery, and allows patients to regain function. At the same time, it does not always work as well as expected. In many cases, patients are not closely monitored over extended periods. The intensity of therapy can also differ, and treatment is not always tailored enough to individual needs. Common tools for assessing motor function include the Fugl-Meyer Assessment, the Modified Ashworth Scale, and the Chedoke-McMaster Stroke Assessment. Even though they are used a lot, these measures sometimes fail to see subtle changes or more complex movement patterns. Results often change depending on the therapist's judgment and the patient's actual participation. Because of this, recovery evaluation is not always uniform (Tsiara et al., 2025).

Recent developments in AI and ML are creating new ways to deal with these problems. These technologies can handle complicated data, such as clinical information, images, and biomechanical signals. AI is already being used in conjunction with robotics, wearable sensors, and virtual reality systems in fields like stroke and spinal cord injury. This combination can help with motor recovery and even predict how well someone will do in the future (Senadheera et al., 2024). A somewhat distinct application is observable in patients with consciousness disorders. This is where machine learning and deep learning are used on brain scans and data on electrical activity. This method can find residual brain activity, which can help make rehabilitation plans more specific (Choo & Chang, 2022).

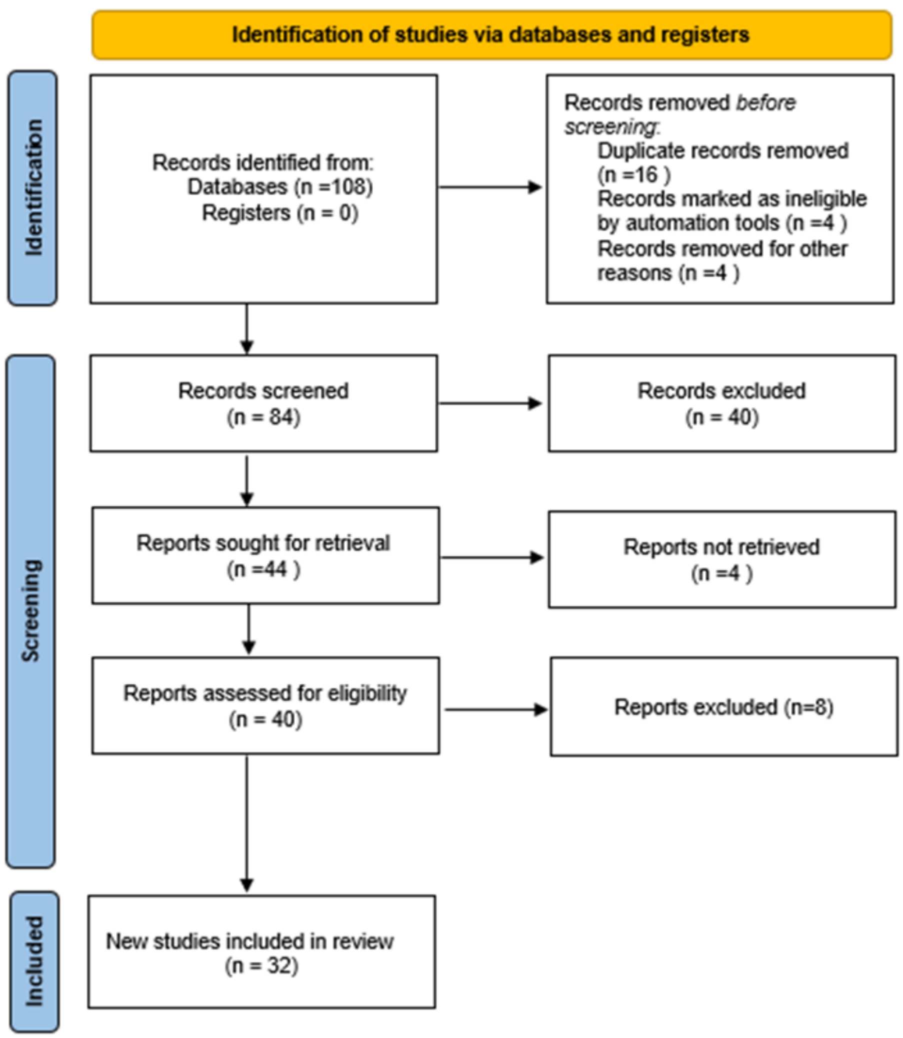

Figure 1. PRISMA flow diagram.

AI is also beginning to branch out into other types of therapy. Radiomics and brain-computer interface (BCI) technologies are new approaches that are starting to change how rehabilitation is delivered. Radiomics uses MRI or PET images but analyzes them differently. It doesn't just look at the scans; it also pulls out quantitative features from them. Some of these characteristics may be associated with disease progression or the patient's response to treatment. This can be useful in clinical practice, especially when decision-making is hard, such as when someone has a neurodegenerative or vascular condition. BCIs function differently. Patients can learn how to move by using their own brain signals to control external devices in non-invasive systems, especially those that use EEG. The goal is to leverage the brain's ability to change, which may help restore functions that have been lost over time (Wei & Wu, 2023).

In this paper, we present a detailed review of AI in neurological rehabilitation, centering on its function in improving motor, cognitive, and functional recovery.

2. REVIEW METHODS

The study is based on the PubMed database. Publications analyzed for that purpose were from 2018 to the present. The articles were in English, with no other languages included.

The keywords used in the search process included “artificial intelligence”, “machine learning”, “deep learning”, ”neurorehabilitation”, “stroke rehabilitation”, “brain-computer interface”, and “virtual reality rehabilitation”. Altogether, we identified 108 publications initially.

The inclusion criteria required that studies show a clear link between the use of artificial intelligence in rehabilitation and its impact on patient outcomes. It was also important that the studies provided a clear, understandable overview, explaining, in a simple and accurate way, how AI tools and methods are used in rehabilitation. After the search, screening, and exclusions, 32 articles met the criteria and were included in the analysis (Figure 1).

3. RESULTS & DISCUSSION

3.1. Stroke Rehabilitation

Stroke is still one of the main reasons people suffer from long-term disability around the world. It may cause enduring problems with movement, thinking, and emotions. Although regular rehabilitation is very important, it can be limited because the way professionals assess progress relies on personal judgment, the amount of therapy may not be consistent, and access to expert care may be difficult (Senadheera et al., 2024).

AI has become more important in neurorehabilitation in the last few years. It can help make evaluations more precise, develop treatment plans tailored to each patient, and make it easier to track patients' progress over time. Computer vision and machine learning tools can work with complex data, such as brain activity, movement patterns, and medical images. This helps doctors monitor how well someone is recovering and adjust their treatment to meet their needs (Heo et al., 2019). A stroke can cause a lot of different problems. Patients may have trouble with walking, using their arms, talking, or thinking. Because of this, more studies are examining how AI can help with rehabilitation across these different areas.

The goal of these systems goes beyond just helping people get better at moving. They are also being used to help people communicate better and do more things on their own. In general, this could lead to more effective and efficient rehabilitation for each patient (Lee et al., 2023a).

3.1.1. Upper Limb Rehabilitation after Stroke: AI and Robot-Assisted Approaches

Rehabilitation of the upper limb following a stroke continues to be difficult. Many patients have long-lasting motor problems, spasticity, and reduced independence. Recent research suggests that AI-driven, robot-assisted, and virtual reality therapies can improve upper-limb function. ArmAssist and ArmeoSpring are two robotic systems often used alongside regular therapy. For example, training with Armeo Spring improved motor function, as measured by the Motor Index (MI). It also reduced spasticity on the Modified Ashworth Scale (MAS) and helped lower pain on the Visual Analog Scale (VAS).

Arm-assisted robotic training showed clear improvements in the Fugl-Meyer Assessment for the upper extremity (FMA-UE) and the Wolf Motor Function Test–Functional Ability Scale (WMFT-FAS). It performed better than standard arm training. It is also relatively low-cost and does not require as much therapist supervision (Mahmoud et al., 2023).

VR technology enables patients to participate in interactive, immersive simulated rehabilitation programs that include both mental and physical exercises. Hand function, patient motivation, and engagement have all improved when game-like approaches were incorporated into therapeutic exercises (Song et al., 2024). Some studies did not find clear benefits of VR over standard therapy. Others, however, reported better results in measures such as NIHSS and the Jebsen-Taylor Hand Test.

Some systems also use external sensors, such as infrared cameras. They keep a closer eye on movement. Sometimes, they are mixed with EEG and EMG signals. This can give feedback during therapy and may help make changes that are better for the patient. When used with regular therapy, this method has been linked to stronger hands and better function. Some studies show that people who have had a stroke for a long time have less spasticity (Mahmoud et al., 2023).

Recent studies have utilized alternative methods, including ARMin exoskeleton therapy and VR mini-games. They are usually safe and possible. Some findings indicate that they may facilitate task-specific motor recovery. Using combined robotics, AI, and VR, it is possible to train harder and more often. It can also make therapy feel more real. These methods can also provide objective ways to track well-being (Chae et al., 2020).

3.1.2. Lower limb robot-assisted therapy

Rehabilitation of the lower limbs is important for getting gait, balance, and mobility back after a stroke. New devices have been made possible by recent progress in robotics and AI. The Multi-Stage Hemiplegic Lower Limb Rehabilitation Robot (MHLRR) is one example. These advanced devices can adapt to meet patients' needs as they progress through different stages of rehabilitation and provide personalized support. They help the joints in the hips, knees, and ankles. It can be used on both the affected and unaffected limbs. Training can occur in seated, supine, or standing positions, facilitating personalized therapy at each stage (Wang et al., 2024). Xsens MVN Link and other motion capture systems can record detailed movements during walking. They enable accurate biomechanics-based movement planning.

AI methods like Symlet wavelet processing can make data better. They help obtain more accurate measurements of joint angles and reduce noise in the signals. The exoskeleton is controlled by adaptive iterative learning algorithms. They closely follow the planned path and can be adjusted based on how well each patient does (Ma & Xie et al., 2025). Initial research indicates that these techniques can successfully replicate human natural gait patterns and customize training intensity to meet individual patient requirements. It keeps helping with functional recovery. Robotic assistance and AI motion analysis work together to make lower limb rehabilitation more accurate, intensive, and personalized.

Further research is necessary involving larger patient cohorts and in practical clinical environments. This will help us determine how well these systems work and whether the results can be applied across many different situations (Lv & Chen et al., 2022).

AI-Assisted Telerehabilitation of Cognitive Function after Stroke

In addition to aiding movement recovery, AI is now being used to support cognitive rehabilitation after stroke (Ji et al., 2023). Services like Zenicog® let patients complete cognitive training exercises from home at their own pace. These systems use AI to monitor patients' progress, predict when tasks might get too easy or too hard, and suggest personalized exercises-all without a therapist being present in real time.

There was a clinical study with 63 patients who were in the subacute phase after a stroke. Some had an ischemic stroke, and others had a hemorrhagic one. In this study, participants completed 24 AI-assisted sessions over six weeks. These patients showed better working memory, as in the Digit Span Forward and Backward tests. Also, their attention and executive functions (Trail Making Test A and B) were improved. Their overall cognitive function, measured by K-MMSE2, was also better than that of the group that only had training with a therapist. Researchers also looked at things like psychosocial well-being, self-efficacy, and depression. No bad events happened during the sessions (Kim et al., 2025).

The results show that AI-assisted telerehabilitation works as well as standard therapist-guided sessions. It also has some advantages. It can reach more patients, is easier to access, and may increase patient engagement, especially in remote or low-resource settings. Additional research is necessary. Subsequent research should examine long-term outcomes, cost-effectiveness, and responses across various patient demographics. This will help make the role of AI in post-stroke rehab clearer (Ji et al., 2023).

3.2. Spinal Cord Injury

3.2.1. AI-Assisted Rehabilitation for Spinal Cord Injury

Rehabilitation plays an important role in helping people with spinal cord injuries regain function after an accident. Unlike early treatment, which focuses on surgery or medication, rehabilitation aims to help patients return to daily activities. The main goal is to improve functional independence and quality of life. Standard rehabilitation plans can be difficult to set up and usually need to be tailored to each patient. This is because injuries and recovery patterns vary from person to person (Rasoolinejad et al., 2025).

But then along comes artificial intelligence, especially when we talk about deep learning – it is going to change the whole face of SCI rehab. AI can automate parts of the therapy process and provide real-time feedback to both patients and clinicians on what is working and what is not. Intelligent rehab systems use machine learning to create individualized therapy plans based on a patient's actual progress. Decision support tools use key variables to help clinicians choose the right rehabilitation program for each patient (Lee et al., 2023b).

AI is making telerehabilitation better. It lets patients get treatment from the comfort of their own homes while still being watched by doctors. AI uses motion analysis algorithms to track patients' movements and provide feedback on their performance. This makes sure that patients do their exercises correctly, even when they are done from a distance.

AI can work together with BCI systems, going beyond what standard physical therapy can do. For patients with severe spinal cord injuries, this technology can let them control prosthetic devices using their brain signals. Deep learning models interpret these signals and turn them into simple commands for the device. This can help people regain some independence and function. At the moment, BCI is still not widely used in clinics. Research is moving slowly, and there are ethical issues. Collaboration between different specialists also needs to improve. More work in these areas could make BCI systems more effective. Over time, this may help patients move better and improve their everyday quality of life (De Miguel-Rubio et al., 2023).

3.2.2. AI-Assisted Upper Limb Rehabilitation in Spinal Cord Injury (SCI)

Recent studies have examined how AI-based systems can support upper-limb rehabilitation in people with spinal cord injuries. One particular study ran a randomized trial involving an AI-driven motion analysis platform that made Thera-band exercises a bit more interactive. Participants trained for 1 hour, three times a week, over eight weeks. One group used an AI system with real-time feedback, while the control group had no computer support. The results did not show a statistically significant difference between the two groups.

The system used a standard webcam with AI software to track movements, count repetitions, and estimate effort (Lee et al., 2023a). This type of real-time feedback may increase patient engagement.

AI-based motion analysis could be a useful addition to standard rehabilitation for patients with spinal cord injury. But before we can be confident that this kind of thing really does make a long-term difference, we need to involve a larger group of people and see how they perform over a longer period (Lee et al., 2023b).

3.3. Traumatic Brain Injury (TBI)

Rehabilitation following TBI is still a complicated and demanding process due to the highly variable and often unpredictable clinical course of patients. Recent studies have shown that AI and machine learning can support clinicians in planning and optimizing rehabilitation. Some studies have used detailed datasets to see how patients recover. These models can sometimes make better predictions than traditional regression methods because they take into account factors such as the patient's age, level of involvement in therapy, and time since injury.

Several papers suggest that tools such as support vector machines and neural networks help predict mortality and complications. Random forests are also used for this. Yet the findings remain inconsistent across the current literature. Part of the problem is the data itself, as datasets vary widely across studies. There is also no single way to define patient outcomes (Appiah Balaji et al., 2023). This makes it very difficult to compare one study to another in a meaningful way.

Machine learning has also been used in hospital rehabilitation. It can help change therapy plans and find patients who might get better faster or slower. These models are more accurate because they use both numerical and categorical data. Overall, the findings suggest that AI-assisted rehabilitation can improve outcome predictions. It can also guide therapy for each patient and support early decisions in the clinic. This is particularly helpful in traumatic brain injury, where standard assessments often struggle because the injuries are complex and vary a lot from patient to patient (Beard et al., 2024).

3.4. Parkinson's Disease (PD) and Other Movement Disorders

AI and machine learning have been studied in Parkinson's disease and related movement disorders. So far, their effect on patient outcomes appears limited. The majority of research focuses on early detection and symptom categorization. Some studies also examine how the disease will worsen. These models can accurately identify different types of diseases or find cognitive problems with moderate to high accuracy. But this level of accuracy doesn't usually lead to big changes in a patient's daily life, motor skills, or quality of life.

Using machine learning enables a closer look at patient data, such as speech patterns, gait, and neuroimaging (Rabie & Akhloufi, 2025). This allows treatments to be adjusted for each person. When we use wearable sensors and remote platforms, we get to see how a patient performs in real time. It is like keeping an eye on their progress 24/7. But we still do not have enough proof that this leads to better long-term results. We need more data to see if these tools truly help people stick to their recovery plans or return to their normal lives.

There are still problems that keep AI from being used in medicine. Datasets are small or don't always follow the same rules. Many algorithms are still hard to understand, a problem often called the "black box" problem. AI can help with earlier diagnosis and more personalized care, but current research shows that there is still a big difference between accurate predictions and real benefits for people with Parkinson's disease (Faouzi et al., 2023).

Further research is needed to connect these predictions with real-world clinical improvements 3.5. Virtual and Augmented Reality Integrated with AI

Neurorehabilitation now uses both virtual and augmented reality along with AI. This makes the setting feel more real, but it also lets the therapist tailor the therapy to the patient. People with Parkinson's disease have already shown that VR can help with balance, walking, and posture control. Some studies show that working out for 20 to 30 minutes a few times a week for a few weeks can help heal faster (Wu & Zhang, 2025).

With the addition of AI, these systems can use sensors and motion-capture technology to monitor patients' progress. Then, based on how well the patient is doing, the exercises can be changed right away. AI gives us a way to tweak how hard a task is on the fly, offering instant feedback while keeping an eye out for early symptoms of cybersickness. This kind of flexibility is a big deal in clinical practice. As noted, VR setups often make the entire process more enjoyable for patients. This boost in motivation is likely why we see people showing up to their sessions more consistently than they do with traditional, often repetitive, physical therapy (Kwon et al, 2023).

3.5. Difficulties and Restrictions

3.5.1. Technical and Clinical Limitations

Using AI in neurorehabilitation is not easy. There are many problems, both technical and clinical ones. Medical records, sensors, and other data sources often do not fit into systems or work as they should. As a result, it is much harder to build models that work across different situations (Lanotte et al., 2023). Many AI systems are still like "black boxes" for the users. They do not explain how they make decisions, which can make doctors less likely to trust them. Clinicians also say that their organizations are not ready to support these technologies. Often, they haven't received enough training or real hands-on experience with AI tools.

AI can help make therapy work better for each patient, which is helpful in real life. It doesn't take the place of what therapists do, though. It is still hard to make a system that can handle things like clinical judgment, understanding emotions, or changing exercises on the fly. AI is better thought of as a tool to support therapy rather than a replacement for it (Alsobhi et al., 2022).

3.5.2. Ethical and Legal Obstacles

People also worry about moral and legal things when AI is used in neurorehabilitation. Informed consent is one of these big issues. In real clinics, it is not always clear if patients really get how these automated systems work. Also, it is hard to say who should be blamed if a mistake happens. This kind of confusion makes it difficult for hospitals to adopt new tools (Tai et al., 2025).

Privacy is a major concern in AI for neurorehabilitation. Neurological data are very sensitive. Because of that, protecting patients' rights is essential. That includes mental privacy and the preservation of their cognitive integrity. What's more, these systems don't just affect physical health-they can also affect mental health (Lanotte et al., 2023).

3.5.3. Economic and Implementation Barriers

But cost is still a major problem. It is often necessary to buy new equipment and software and to train staff to use AI in clinical rehabilitation. Many centers find this hard to handle. Smaller facilities or those with fewer resources may have an even harder time. Because of this, not everyone can use these technologies. Another problem is that there aren't always clear rules and not enough information on long-term results. This makes it harder for more people to use it. More evidence on cost-effectiveness would help clinicians and decision-makers when considering whether to implement these systems (Tai et al., 2025).

3.6. Human AI-collaboration

AI is slowly making its way into neurorehabilitation, but the field is still young. Therapists are experimenting with ways to make AI easier to follow. Tools such as gradient-based visualizations and saliency maps can highlight key moments in a patient's movements. This gives clinicians useful information and reduces the need to guess what is happening during therapy. These models tend to work better when they use different types of data. This can include imaging, sensor data, clinical notes, or lab results. Using multiple sources gives a broader picture.

Therapists often use tools like SHAP and GradCAM to understand how the AI arrives at its decisions. Each of them shows something from a different perspective. The other can show where the movement changes (Zheng et al., 2023). Moving rehabilitation into the home setting is a promising step forward. These systems use wearable sensors to allow for remote patient monitoring. The software can adjust the difficulty of an exercise while the patient is performing it. This provides feedback immediately. Doctors and AI can work together to pick the best treatment path. Often, this gives patients more control over their recovery. In the years ahead, a mix of explainable AI and diverse data types should make therapy safer. It will also be more effective and easier for most people to access (Atf & Lewis, 2022). The study summary is presented in Table 1.

Table 1. Summary of key studies and their findings on the use of artificial intelligence in neurorehabilitation.

Study	Year	AI application	Main findings
Kim et al.,	2025	Cognitive telerehabilitation after stroke	AI-driven sessions (24 sessions/6 weeks) improved working memory and executive functions similarly to standard therapy.
Tai et al.,	2025	Acute spinal cord injury (SCI)	Explainable AI (XAI) and multimodal data can effectively predict recovery outcomes and help in clinical decision-making.
Chae et al.,	2020	Home-based upper limb rehab (smartwatch)	A machine learning model using smartwatch data can accurately monitor and evaluate home exercises for chronic stroke survivors.
Ma & Xie	2025	Acute ischemic stroke (independent gait)	Machine learning techniques showed high accuracy in predicting independent gait recovery in patients with anterior circulation stroke.
Rasoolinejad et al.,	2025	Inpatient rehabilitation for SCI	ML models can predict functional improvements (FIM scores) based on initial clinical data, allowing for better therapy planning.

4. CONCLUSION

AI has shown considerable potential to transform neurological rehabilitation across a variety of conditions, including stroke, SCI, TBI, and movement disorders such as PD. It draws on multiple technologies. Machine learning, deep learning, robotics, brain-computer interfaces, and virtual or augmented reality all play a role. Together, these tools enable therapy that appears to be adaptive, personalized, and data-driven. Patients can improve motor skills, cognitive functions, and daily functioning. Evidence indicates that AI-supported interventions - like robot-assisted training for upper and lower limbs, telerehabilitation platforms, and immersive VR environments - can increase therapy intensity. They also give continuous feedback and help keep patients engaged. The results can be seen in real improvements. Patients often show improved motor function, enhanced cognitive abilities, and a higher overall quality of life.

Even with these improvements, the picture is still not very clear. There are still many problems that make it hard to put into practice. For instance, datasets often don't match up, which can make these systems less reliable in clinical settings. When it comes to Parkinson's disease, the situation is a little bit mixed. AI can be highly accurate at tracking symptoms and building predictive models. Still, it's not clear whether this actually leads to improvements in how people do everyday things.

Looking ahead, there are several promising directions. One key area is Explainable AI. Another is integrating data from multiple sources to get a fuller picture. There is also growing interest in using AI in home-based rehabilitation and in having people work with robots to improve therapy. Clinicians can make predictions and change therapy with confidence when they use models that are easy for them to understand. While combining information from clinical records, imaging, and sensor data, it is possible to make interventions more reliable and better suited to each patient's needs. With home-based AI systems and the ability to monitor patients from a distance, we have been able to extend our reach in providing therapy while still keeping an eye on patient safety and engagement. The idea isn't for AI to completely replace the expertise of human therapists, but rather for it to work in tandem with them, augmenting the decision-making process & really putting the patient front and center in the care they receive, also making it more efficient and more tailored to individuals. All these things point to AI-driven neurorehabilitation having real potential to help us improve recovery, use our resources more effectively, and ultimately provide better care to patients with neurological disorders.

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