Impact of AI-Powered Solutions in Rehabilitation Process: Recent Improvements and Future Trends

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Abstract: Rehabilitation is an important and necessary part of local and global healthcare services along with treatment and palliative care, prevention of disease, and promotion of good health. The rehabilitation process helps older and young adults even children to become as independent as possible in activities of daily life and enables participation in useful living activities, recreation, work, and education. The technology of Artificial Intelligence (AI) has evolved significantly in recent years. Many activities related to rehabilitation have been getting benefits from using AI techniques. The objective of this review study is to explore the advantages of AI for rehabilitation and how AI is impacting the rehabilitation process. This study aims at the most critical aspects of the rehabilitation process that could potentially take advantage of AI techniques including personalized rehabilitation apps, rehabilitation through assistance, rehabilitation for neurological disorders, rehabilitation for developmental disorders, virtual reality rehabilitation, rehabilitation of neurodegenerative diseases and Telerehabilitation of Cardiovascular. We presented a survey on the newest empirical studies available in the literature including the AI-based technology helpful in the Rehabilitation process. The novelty feature included but was not limited to an overview of the technological solutions useful in rehabilitation. Seven different categories were identified. Illustrative examples of practical applications were detailed. Implications of the findings for both research and practice were critically discussed. Most of the AI applications in these rehabilitation types are in their infancy and continue to grow while exploring new opportunities. Therefore, we investigate the role of AI technology in rehabilitation processes. In addition, we do statistical analysis of the selected studies to highlight the significance of this review work. In the end, we also present a discussion on some challenges, and future research directions.

Keywords: artificial intelligence, machine learning, rehabilitation, healthcare, cognitive skills, cognitive rehabilitation

Introduction

Cognitive decline is associated with loss of cognitive skills, and it is common with aging but it gets worse if it is caused by some medical conditions like neurocognitive disorder or neurodegenerative disorder. With the loss of cognitive skills like reasoning, thinking, executive functioning, attention, memory, and other abilities, an individual may face difficulty in the activities of daily life. The lack of necessary treatment for individuals with mental health issues is a significant concern. Therefore, an appropriate care and rehabilitation facilities are important for people having cognitive impairments.[1]

Cognitive Rehabilitation Therapy (CRT) is a cognitive activity that helps people with cognitive decline to reestablish their previous cognitive skills or helps in learning new cognitive skills.[2] Rehabilitation is of two types, Restorative and Compensatory rehabilitation. It is a non-pharmacological method of treatment as it uses problem-solving techniques to help people with cognitive decline sustain their daily life activities.[2] In addition, the implementation of cognitive training may be employed to enhance cognitive abilities in individuals with no impairments.[3] It can also be utilized to augment academic achievement in students or bolster cognitive reserve in older persons.

Digital technologies in healthcare, including AI in mental health, have indeed revolutionized the field by offering a wide range of applications.[4] Machine learning has made significant advancements in the field of healthcare and specifically, reinforcement learning has made treatment interventions personalized.[5] The applications of AI in mental health extend beyond diagnosis and drug recommendation.[6] Virtual therapy sessions using AI chatbots or virtual reality platforms have shown promising results in providing accessible support thus, offering a safe environment for patients to express their thoughts and emotions, facilitating effective therapy without geographical barriers.[7] One of the primary advantages of technology-based interventions is their enhanced accessibility.[8] Unlike traditional methods, these technology-based interventions are often cost-effective and can be easily accessed by individuals from the comfort of their own homes.[9,10]

A wide range of CRT interventions for mild cognitive impairment (MCI) or neurocognitive disorders can be implemented through smartphone apps, web-based applications, or gaming consoles without acquiring expensive equipment[9] as shown in Figure 1. Such interventions can be made adaptive by using a reinforcement learning agent that interacts with the trainee during each exercise/task. Based on the performance of the trainee, a tailored policy is pursued making training interventions personalized and adaptive. Such personalization of treatment will maximize the effectiveness of cognitive training programs.[11]

Recent technological advancements have made it possible for therapists to conduct traditional interventions via social robots, eliminating the need for traditional paper-and-pencil methods.[12] With a heterogeneity in it, social robots include humanoid robots like MATILDA, MERO, NAO, PEPPER, SILBOT, SOPHIE etc[13,14] and zoomorphic robots like AIBO and PARO.[15] Although using humanoid robots as a mediating tool has shown potential in engaging participants in memory training programs[12] yet to gain a better understanding of the training components and robot responsiveness, additional studies are required.
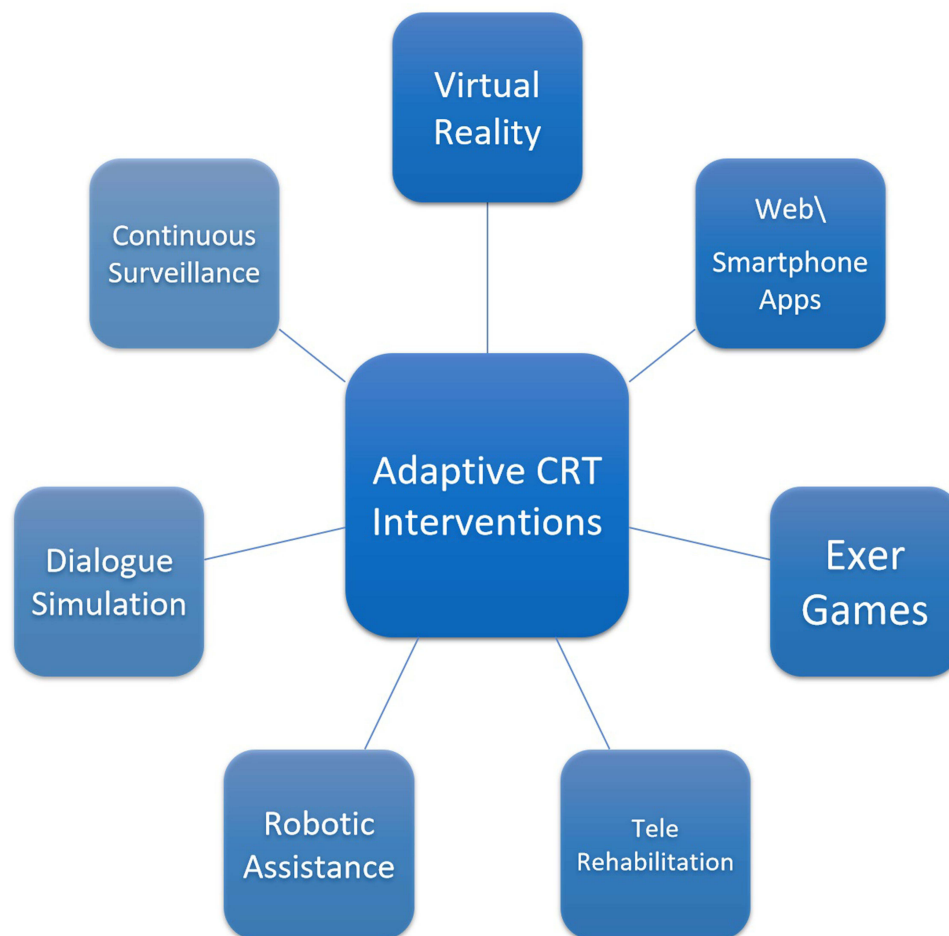

Figure 1 AI-based adaptive cognitive rehabilitation therapy (CRT) interventions.

Along with these merits of technology-based CRT, some challenges need to be addressed. The most significant challenge among all is the adoption of rehabilitation techniques and the factors influencing adoption include cost, trust in technology, and access.[16] Others include less education, lack of awareness, improper training, and unavailability of user-friendly interface.[17] However, it is essential to note that AI should never replace human expertise in healthcare. Instead, it should be seen as a valuable tool that complements the skills of healthcare professionals. The combination of human judgment and AI-driven insights can improve diagnoses, personalized treatment plans, and patient care overall.

This study aims at the most critical aspects of the Rehabilitation process that have benefited from the use of AI, including Personalized Rehabilitation Apps, Rehabilitation through Assistance, Rehabilitation for Neurological Disorders, Rehabilitation for Developmental Disorders, Virtual Reality Rehabilitation, and Rehabilitation of Neurodegenerative Diseases. The primary focus of this survey is to identify personalized and adaptive AI-based interventions for individuals with cognitive impairments. It includes interventions for neurodevelopmental disorders (ie Autism spectrum disorder (ASD), Attention deficit hyperactivity disorder (ADHD), learning disorder), neurocognitive disorders (i.e, stress, anxiety and depression, brain stroke, etc), and neurodegenerative disorders (i.e, dementia, Alzheimer's disease (AD), Parkinson's disease, etc).

I. RELATED SURVEYS AND SELECTION PROCESS This section consists of two parts, where the first subsection highlights some recent survey papers related to AI technology or the rehabilitation process. We review the main contributions of each article as well as limitations concerning the scope of our contribution. The second subsection presents the survey studies' selection criteria, including the search strategy, inclusion criteria, and data synthesis.

Related Surveys

It is important to have effective treatments for all diseases including neurodegenerative diseases. Therefore, the review work in[18] highlights the Machine Learning (ML) applications for early diagnosis, discovery of new therapies, and interpretation of medical images. They discussed how high-dimensional sources of data are utilized in various ML applications for neurodegenerative diseases. However, the article fails to cover diverse rehabilitation processes based on AI methods. Similarly, the review work in[19] presents diverse types of personalized robot behavior patterns. Different schemes from the area of child–robot interaction and human-robot interaction are discussed. The authors compare them using their deficits, potential usability, and feasibility for autism-specific robot-assisted therapy. During therapeutic games, one limitation on the methods used by robot to learn interaction strategies is to give more autonomy to robot and it is linked with a robot's decision-making. The article does not address the potential uses of AI and ML in various rehabilitation processes.

Considerable work done in[20] where authors consider older patients with dementia and mild cognitive impairments and identified rehabilitation plans as well as cognitive stimulation and training. The authors provided a qualitative synthesis of the study characteristics and features of every software. The studies found on cognitive intervention software highlight that several technological plans are available for people with MCI and dementia. This study does not provide comprehensive information about the AI-based rehabilitation process but can be used to distinguish between programs if they have different characteristics, usage modes, and objectives. The review work of[21] highlights developments and issues in human–robot interaction perspective assistive robotics and rehabilitation. The authors also identify various subdomains in rehabilitation and assistive robotic research.

A significant work reported in[4] where authors have presented reinforcement learning based diverse healthcare applications including precision medicine, control systems, personalized rehabilitation, dynamic treatment regimes, diagnostic systems, healthcare management systems, medical imaging, and dialog systems. Although this survey article covers many intelligent healthcare applications, it presents a few RL-based applications in personalized rehabilitation. Recently wearable technology proved useful in rehabilitation, assessment, diagnosis, and monitoring.[22] Therefore, the applications of review wearables by Parkinson's disease patients as well as patients with neurocognitive disorder are discussed in.[22] However, regarding the rehabilitation process, this study only considers existing wearable insoles and their use in rehabilitation.

We summarize about mentioned relevant studies, their limitations with respect to the scope of our work and our contributions in Table 1. The contribution of this article is to analyze the impact of AI-enabled solutions in various Rehabilitation processes including Personalized Rehabilitation Apps, Rehabilitation through Assistance, Rehabilitation for

Table 1 A Brief Comparison of Related Surveys in Terms of Contributions and Limitations

Article Ref- erence	Year	Area	Contribution	Limitation
[18]	2020	Neuro-degenerative diseases	ML applications for neurodegenerative diseases	No discussion on rehabilitation process
[19]	2022	Autism therapy ap- plications	Presents diverse types of personalized robot behaviour patterns	No work on AI-based rehabilitation process
[20]	2020	MCI and dementia	Presents various technological programs for people with MCI and dementia	- Only considers older people with MCI and dementia - Do not consider works after 2018
[21]	2020	Human-robot interaction in assistive and rehabilitation robotics	Highlights developments and issues in human-robot interaction perspective assistive robotics and rehabili- tation	Do not consider other types of rehabilitation
[4]	2020	Healthcare applica- tions	Healthcare applications: precision medicine, control systems, personalized rehabilitation, dynamic treat- ment treatment regime, diagnostic systems, healthcare management systems, medical imaging and dialog systems.	Only a few RL-based applications for per- sonalized rehabilitation
[22]	2020	Wearable technology	Applications of wearable technology in Parkinson's dis- ease patients as well as patients with neurocognitive disorder	Only considers existing wearable insoles and their use in rehabilitation.
Our work	2023	Diverse rehabilita- tion process	Diverse AI-powered solutions for Rehabilitation in- cluding Personalized Rehabilitation Apps, Rehabili- tation through Assistance, Rehabilitation for Neuro- logical Disorders, Rehabilitation for Developmental Disorders, Virtual Reality Rehabilitation, Rehabilita- tion of Neurodegenerative Diseases Telerehabilitation of Cardiovascular & Other Disease.	Studies before 2020 are not included

Neurological Disorders, Rehabilitation for Developmental Disorders, Virtual Reality Rehabilitation, and Rehabilitation of Neurodegenerative Diseases.

Selection Process

The standard guidelines that have been adopted in this review work are that of the PRISMA statement[23] as shown in Figure 2. For example, first, we employed a combination of keywords and research queries such as rehabilitation, artificial intelligence, adaptive cognitive rehabilitation, personalized rehabilitation, cognitive rehabilitation for MCI, computerized cognitive training with reinforcement learning, rehabilitation for neurocognitive and neurodegenerative disorder, etc as also indicated in Figure 2. In the next step, we utilized popular search database sources, including IEEEXplore, SpringerLink, ScienceDirect, Google Scholar, Nature, and ACM Digital Library. Our priority is on the studies published after review process in journals, book chapters, and conferences. We gave preference to top-ranked journal studies, and our review contains about 90% journal papers. It was challenging to include all different sorts of deficits because cognitive rehabilitation (CR) includes a wide range of mental illnesses. Rehabilitation for brain tumors, brain injuries, drug addiction, epilepsy, and stress/anxiety induced by other diseases, like, HIV or cancer, are not included in this study.
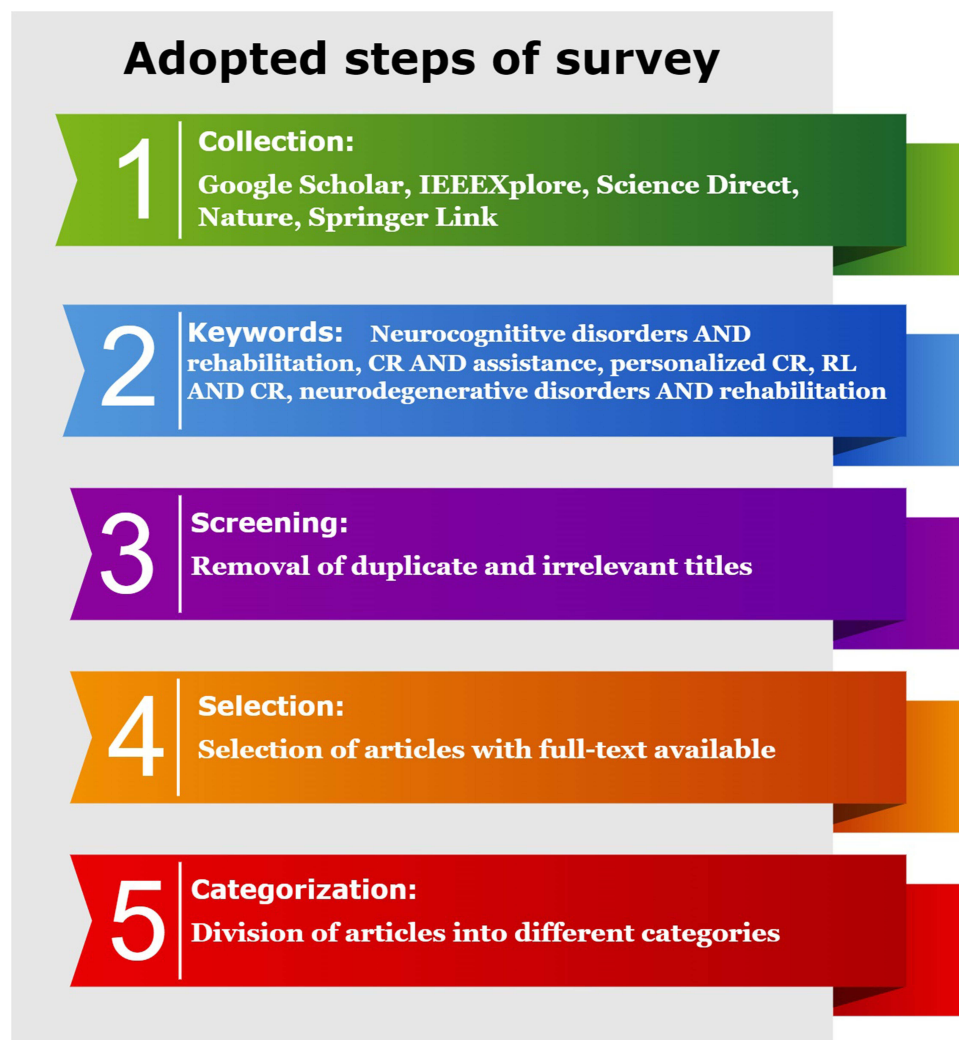
Adopted steps of survey

1 Collection:
Google Scholar, IEEEXplore, Science Direct, Nature, Springer Link

2 Keywords: Neurocognititve disorders AND rehabilitation, CR AND assistance, personalized CR, RL AND CR, neurodegenerative disorders AND rehabilitation

3 Screening:
Removal of duplicate and irrelevant titles

4 Selection:
Selection of articles with full-text available

5 Categorization:
Division of articles into different categories

Figure 2 Steps involved in the present survey.

Following the PRISMA guidelines, we collected about 300 studies, but some of them were removed due to duplication and our criteria for inclusion as shown in Figure 3. However, some articles were removed that do not match the following eligibility criteria:

- Published from 2020 to 2023.
- Relevance of the AI-based method in any aspect of a rehabilitation process.
- Full-text availability.
- Academic empirical and theoretical studies.
- Peer-reviewed studies.
- English language.

Background
Preliminary to Rehabilitation
This subsection presents a brief introduction to rehabilitation, in particular to cognitive rehabilitation. The last part of this section outlines the reasoning behind the six chosen categories for this review work.
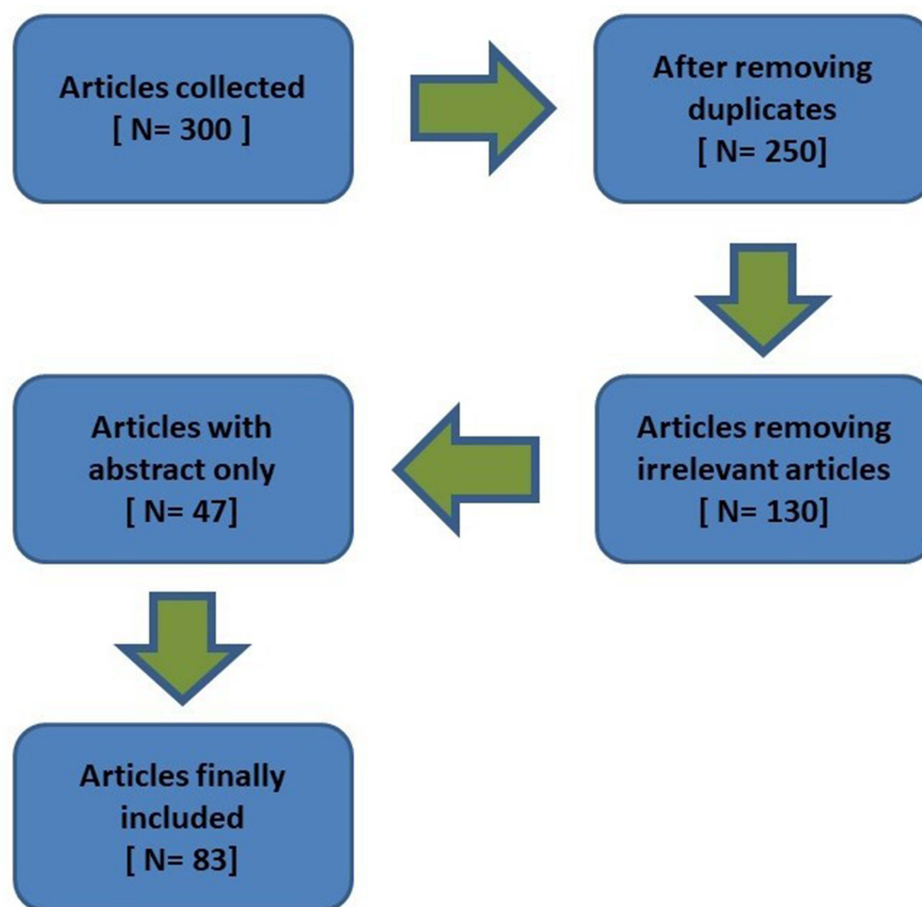
Figure 3 Articles selection process following PRISMA.

Neurological Populations (eg, neurodevelopmental disorders, neurodegenerative diseases, stroke, disorders of consciousness, rare genetic syndromes) may experience daily difficulties while dealing with environmental requests. Intellectual disabilities, extensive motor impairments, sensorial deficits, and communication delays (eg, lack of speech) may be included. Their clinical conditions rely on persons with acquired brain injuries on both families and/or caregivers' assistance.[24,25] This situation may be seriously deleterious for their quality of life and their social image, status, and desirability may be significantly hampered.[26,27] To tackle this issue, assistive technology, new technologies, and artificial intelligence-based programs or interventions may be envisaged.[28–30] Assistive technology-aided treatments include any piece, device, tool, or equipment capable of ensuring individuals suffering from neurological consequences with self-determination and independence towards their environment. Thus, a functional bridge between the behavioral repertoire and the environmental requests may be built.[11] New technologies (ie, virtual and augmented, reality, mixed and extended reality, serious games) may provide immersive scenarios similar to real life, pursuing assessment, educational, and rehabilitative purposes.[31,32] AI with Reinforcement Learning (RL) as branch of ML may represent an interactive way to support users with individualized solutions by learning and being reinforced by their performance.[33,34] The above-detailed technology-based solutions may be implemented in daily and clinical settings for diagnostic and functional recovery objectives and may be considered complementary to standard cognitive rehabilitation. Both may contribute to an accurate and valid help to support the neurological population.[35,36]

Cognitive Rehabilitation (CR) usually refers to systematic and specific cognitive therapy aimed at enabling personal functional modifications through (a) restoring or enhancing already acquired patterns of behavior, or (b) teaching or improving new patterns of cognitive activity and compensatory processes for impaired neurological systems.[37] Accordingly, CR commonly defines either restorative or compensatory strategies. Restorative schemes are developed

on the principles of learning and exercise. The repetitive exercise of neural connectivity assisting cognitive function improves the learning process of novel skills which can restore the damage. Restorative strategies are based on neuronal plasticity. Hence, the intact or non-impaired neurons and neural circuits will replace lost functions. On the other hand, compensative approaches imply the replacement of the neural pathways previously needed to obtain a certain activity. By substituting functional mechanisms, modalities are acquired to get particular objectives. Both strategies may be combined in a rehabilitative program due to the fact that simulation of cognitive processes during compensatory training can improve and support neural connectivity.[38,39]

CR may be delivered via conventional approaches as well as through computerized solutions mediated by the use of Information and Communication Technologies (ICT).[40] Computer-mediated interventions overcome some limitations of conventional strategies. For instance, human resources, time and cost can be handled by using computerized systems. Response time, stimuli delivery and task difficulty can change regularly and can be adjusted to the participant's features and performance.[41,42]

We identified seven main categories. Four categories are named after treatment interventions while the rest after mental illness/disorder. There is a broad spectrum of further impairments that come under the umbrella of neurodegenerative diseases, neurodevelopmental disorders, and neurocognitive disorders. The first category labelled Personalized Rehabilitation Apps includes some illustrative examples of highly customized and tailored solutions in which adapted apps and software were used to support CR in neurological populations with different targeted behaviors and technological options implemented. The second category labelled Rehabilitation through Assistance emphasizes the importance of physical robots or technology-aided programs to support individuals with severe to profound neurological impairments involved in the management and the achievement of daily activities. The third category, labelled Rehabilitation for Neurological Disorders, provides the reader with an overview of cognitive-behavioral therapy focused on helping persons with neurological diseases like depression, anxiety and other mental illness in daily independent functioning.

The fourth category labelled Rehabilitation for Developmental Disorders, is centered on children and adolescents with neurodevelopmental delays. Different technology-based programs were detailed that highlight different ways of helping children to survive independently. The fifth category, labelled Virtual Reality-based Rehabilitation, refers to new technologies. Thus, virtual reality setups may involve users in immersive situations similar to real life enabling participants, clinicians, and researchers with high ecological validity, behavioral tracking, and experimental control. The sixth category, labelled Rehabilitation for Neurodegenerative Diseases, is specifically targeted at technological interventions in individuals with either cognitive or motor extensive impairments. The last category labelled Telerehabilitation for cardiovascular and other diseases is targeted to highlight the role of telerehabilitation for various diseases. It not only encompasses evaluation and monitoring, but also intervention, supervision, education, consultation, and coaching. The idea was to provide readers with a comprehensive although not exhaustive picture of AI and technological- aided treatments in neurological disorders.

Preliminary to Artificial Intelligence

Artificial Intelligence (AI) refers to the creation of a computer system (machine) capable of performing tasks that require human intelligence (smarter than humans) like reasoning, perception, problem-solving, language processing, etc. AI has changed our way of living and it has revolutionized technology through its ability to support, enhance, empower, and inspire humans practically. Artificial Intelligence is a computational approach that enables computers to learn from data and find approximations for difficult problems. AI has been extensively used in large-scale fields including robotics, airline flight control, and healthcare because of its flexibility and robustness. In Psychology, learning is an experience-based process that results in a change in behavior or understanding for better performance.[43] The scientific study of algorithms and statistical models applied to computer systems performing particular tasks is known as Machine Learning (ML) and is acknowledged as a domain of AI. The field involves the autonomous construction of mathematical models by ML algorithms using sample data, or training data, to make predictions or judgments without being primarily programmed to do the task.[44] ML encompasses a wide-ranging field that incorporates diverse paradigms, including supervised, unsupervised, online, batch, meta-learning, and reinforcement learning. Its applications span across various domains, such as medicine, computer vision, agriculture, email filtering, and speech recognition.[11] Among all types of ML, reinforcement learning (RL) is an AI-based adaptive method used to train and improve systems by interacting with

their environments.[45] RL makes decisions and adapts its behavior based on the feedback signal and is often used to solve complex problems.[46]

Deep learning (DL) is the fastest-growing field of data science and is built on artificial neural networks to tackle unstructured data including image and video processing, text, voice, etc. The field has been in account since the 1980s but it reached its full potential during the last few years.[47] Neural networks used by DL are trained end-to-end to make the challenges easier to solve, but sometimes, such techniques are not considered user-friendly due to their steep learning curves.[48] Additionally, several domain-specific restrictions are hindering the widespread adoption of deep learning in various industries.

Impact of Ai in Rehabilitation Process

This is the main section of this study where we analyze the diverse applications of AI-powered techniques in Rehabilitation process as indicated in Figure 4. Moreover, we have summarized a few studies from each category in Table 2.
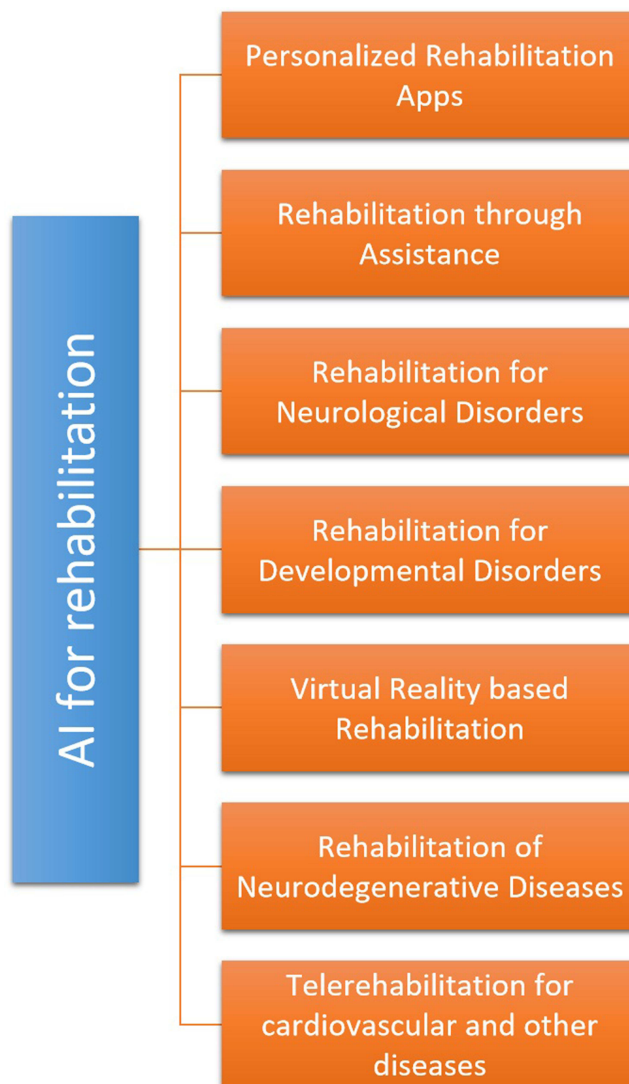

Figure 4 Layout of the Section IV.

Table 2 Summary of Different Studies to Highlight Their Objective, AI Technology and Methodology

Ref	Year	Category	Technology	Methodology
[49]	2021	Apps	Smartphone Games	Games, PlayerPref for storing data in a local database, NLP, Q-learning
[50]	2023	Apps	Smartphone App using MS-Rehab	Intelligent Tutoring System, SARSA algorithm
[51]	2018	Apps	MCI classifier and RL agent	Deep Q- network (dialogue agent), NLP, MCI classifier
[52]	2023	Apps	Mobile App	Netnography (combination of words from ethnography and the internet)
[53]	2020	Apps	Mobile App	1-task analysis, 2-choose the representative tasks, 3-find existing interfaces, 4-rough out the design, 5- analyze the user interaction, 6-create a prototype, 7- test design with users, 8-iterate, 9-build the design.
[54]	2022	Assistance	RL and DL	CNN (ResNet-50, VGG-16, MobileNet) Transformers, RL (Q-learning)
[55]	2022	Assistance	WEB APP and DL	VGG-16, SSD ResNet50 RESNet 34 REST ser- vices, Spring Boot, Spring Data JPA, Apache Maven, Thymeleaf, HTML, MySql, Flask, WebSockets, Im-ageZMQ, OpenCV, Google Text to Speech, and OMX- Player
[56]	2022	Assistance	Robot Assistance named LOLA2	LIDAR sensor, ROS navigation stack, Adaptive Monte Carlo Localization, 3D CNN model trained on UCF- 101 dataset
[57]	2022	Neurological disorder	RL, CBT, Hierarchical Bayesian estimation	Computational model-based RL to investigate the neu- rocomputational substrates
[58]	2021	Neurological disorder	Computer-based Intervention	Core and HomeCore, Core is hospital based software while HomeCore is designed for home exercises
[59]	2023	Developmental disorder	WEB APP	"BEHAVE app for data collection and analysis for accurate and efficient decisions
[60]	2023	Neurological disorder	RL and logistic regression	Study of brain pattern through model based RL and MF-RL
[61]	2020	Developmental disorder	RL	A student NN model, POMDP, and RL, Categorical cross entropy
[62]	2023	Developmental disorder	PC APP	Simple Games
[63]	2022	Developmental disorder	RL	RL, RALF software's: Visual Studio, Dot Net Framework 4.5, DevExpress Components, DevExpress Forms
[64]	2022	Neuro-degenerative	RNN and LSTM	RNN/LSTM (ridge regression, random forest and a one-dimensional CNN for comparison) R, Python
[65]	2022	Neuro-degenerative	PC APP	Customization of intervention according to the level of the patient's cognitive disorder
[66]	2021	VR	VR	Reh@City v2.0 Unity 3D game engine, PC and joy- stick, Task Generator, 11 personalized tasks (attention, memory, language, executive functions) in pdf format
[67]	2022	VR	Virtual 3D cube for gaming as well as home-based PC Exergames	3D walled ExerCube, gloves integrated with HTC Vive trackers for on-body feedback, Flashing lights, vibration, and sound for user feedback

Personalized Rehabilitation Apps

Adaptive rehabilitation is tailored according to the requirements and impairment level of an individual, most of the rehabilitation interventions come in the form of web applications smartphone applications, or a combination of both. This section contains studies with treatment intervention in the form web/smartphone app for different kinds of impairments.

The study in[49] describes a custom Android application designed for dementia patients that uses games and activities to improve cognitive function. The application is designed to target four cognitive domains of dementia: concentration and attention, executive functioning, language improvement, and memory. Each participant practiced the game for a month, with and without reinforcement learning (RL), and the results showed that training with RL produced better outcomes. The study of[50] aimed to rehabilitate Multiple Sclerosis (MS) patients with mild cognitive impairments using a personalized adaptive system. The system combined a computerized cognitive training program with an RL agent. The study had two phases, and the performance of trainees was measured with the Paced Auditory Serial Addition Test (PASAT) before and after the training. The results showed that trainees who trained with RL showed better results than those who trained without RL. MCI can lead to dementia, specifically Alzheimer's disease, as cognitive decline progresses.

In,[51] authors proposed an RL framework by using recorded conversations of normal and MCI individuals with expert interviewers and fed them in a supervised learning model that distinguishes between normal individuals and MCI patients. The agent was trained for disease-specific lexical probability distributions which engage the agent and individual in conversations for diagnosis accuracy with less number of dialogue turns. The clinical trials of the proposed framework prove its effectiveness and it outperformed prevailing supervised learning methodologies significantly.

The investigation of the study[68] suggests that computer-assisted cognitive behavior therapy has the potential for wider-spread implementation as an efficient, acceptable, and effective treatment for depression in primary care. The authors have performed randomized clinical trials and they suggest this with a modest amount of clinician support. The method is more beneficial for patients with depression in primary care, who have a lack of internet access, and low levels of education, income, and reading proficiency. Smartphone-assisted interventions could be efficacious in treating a few forms of generalized anxiety disorder. Therefore, smartphone-based trials were done on college students in.[69] The students with self-reported generalized anxiety disorder were randomized to receive guided self-help from a smartphone or no treatment. Post-treatment after a six-month follow-up outcome contains the state-trait anxiety inventory-trait, the Penn State worry questionnaire, and the depression anxiety stress scales-short form stress subscale.

The authors of[52] have designed a mobile application for children with Autism Spectrum Disorder (ASD). Focusing on simple icons and letters with a maximum of three colors, the aim was to develop a mobile application that can fulfill the special needs of children with ASD not only in schools and therapeutic sites but also at home. Assistive technology applications, such as mobile apps, can enhance social and language skills in young children with ASD, benefiting both parents and children. In,[53] an app is developed to specifically improve numeracy skills in children with ASD. Many apps are already available for teaching numeracy skills to children but this app is developed in a user-friendly way by keeping focus on icon size, display, graphics, soft touch, background sound, etc to grab the attention of children with ASD.

In,[70] a cognitive rehabilitation program is being discussed to help children with ADHD through the use of games and Unity3D technology. UNITY3D is a game engine capable of creating web-based applications that can be integrated into both computers and mobile phones, comprising four functional modules, with the cognitive training module being the core component. The training module employs targeted games to help children overcome their illness, improve their ability to integrate into society, and contribute to their overall treatment. Cognitive incapacity, characterized by cognitive and physical impairment, requires rehabilitation interventions. The study of[71] introduces Brain m-App, developed for home-based cognitive rehabilitation of incapacities. It focuses on improving executive functions, attention, and spatial memory. Brain m-App consists of a 10-day program that uses virtual reality along with 360-degree videos, making it well-suited for home-based rehabilitation. Based on a small clinical study, Brain m-App was found to have improved executive functions and memory performances.

The study in[72] aimed to design and analyze the feasibility of an interactive physical-cognitive game-based training system for older adults. The first phase consists of exercise prototypes while the second phase involves different cognitive games. Participants rated their enjoyment level and provided positive feedback on the well-designed interactions and interfaces. Physical-cognitive game-based and interactive exercise program for older adults shows promise for

fall risk reduction, but effectiveness needs further examination. The work of[73] compares Serious Games (SG) with traditional methods (TM) for cognitive rehabilitation (CR) in healthcare. SG is considered a useful tool to connect healthcare specialists with patients and track their rehabilitation progress. The study includes a literature review, conceptual research, and a model to assess the impact of SG on CR. Specific SG applications like CogniFit, KiMentia, and Sea Hero Quest are mentioned, which focus on cognitive areas like attention, memory, coordination, and reasoning. SG is found to be superior to TM in enhancing training and generating high-quality data for analysis in a secure environment.

The objective of the study in[74] is to implement the GREAT Cognitive Rehabilitation intervention for individuals having mild to moderate dementia. The strategy used to implement the intervention involved identifying and supporting leadership, conducting collaborative planning, training, and assisting practitioners. The outcome evaluation indicated that the intervention was received positively by the local steering group members, practitioners, and service users. People with dementia, their caregivers, and practitioners gave positive feedback about the intervention. The study[75] aimed to evaluate the usability of a stepping exergame among older adults with the major neurocognitive disorder (MNCD) living in long-term care facilities. The study used a mixed-methods approach, where participants played the exergames and provided feedback using the think-aloud method, field notes, and interviews. The study included 22 participants with MNCD and found that the stepping exergame was user-friendly and suitable for older adults with MNCD.

The authors of[76] aimed to assess the effectiveness of a cognitive training app named MeMo, designed to improve behavioral and cognitive performance in people with neurocognitive disorders. The study concluded that MeMo was effective in enhancing behavioral and cognitive performance in individuals with neurocognitive disorders if used regularly. The purpose of the study in[77] is to evaluate the effectiveness of the self-administered mobile cognitive training intervention called "NeuroNation MED" in individuals with Mild Cognitive Impairment. The study will provide insights into the effectiveness of mobile training on cognitive endpoints, neuropsychiatric symptoms, usability, and participant engagement.

Rehabilitation Through Assistance

Patients with down syndrome, brain stroke, and severe dementia are unable to perform their activities of daily living (ADL) on their own. Hiring a professional caregiver to assist such individuals costs a lot. Hence, to make such individuals being able to perform their daily activities rehabilitation can be done by assistance, ie, robot assistance, AI-based dialogue therapists/simulators, etc.

In,[78] the authors developed an assistive system to help Alzheimer's patients perform daily tasks such as drinking a beverage. The system extracts the position of the patient's body joints, and the patient's exact position during an activity. The RL agent analyzes all activities and generates an alert in case of an anomaly. The system's real-time effectiveness was evaluated using precision and recall metrics, proving it to be the most suitable system for assisting Alzheimer's patients in performing daily activities. In,[54] the authors proposed a support system for the support of Alzheimer's disease patients to help patients perform their tasks on their own. This assistive system consists of human activity recognition (HAR) systems, one with 2D skeleton data and a second with 3D skeleton data followed by CNN and transformers. The work concludes by comparing the proposed system's performance to determine the most suitable assistive system among all.

In another study,[55] an AI food assistance for AD patients is considered. Alzheimer's patients are at high risk of dehydration, malnutrition, or overeating due to memory loss. This system assists the patient's activities through video, monitors their timing of eating and drinking, and generates audio messages to stop them from overeating or to remind them to take their meal. The results proved the efficiency of application hence reducing the need for professional caregivers for patients. In,[56] an assistive robot named LOLA2 has been developed, for the assistance of people with neurodevelopment disorders. The robot LOLA2 monitors real-time actions of a patient by monitoring the time and action of activity. The results obtained were acceptable enough to conclude that LOLA2 can perform as an assistant for neurodevelopmental disorders people.

The development of the M3Rob rehabilitation platform that integrates haptic robotics, neurofeedback, and augmented reality to aid in stroke rehabilitation is performed in.[79] The M3Rob platform leverages electromyography (EMG) and electroencephalography (EEG) signals to identify the intent of hand and wrist movements, enabling personalized assistive therapies for neuromotor and cognitive rehabilitation. The research in[80] develops an ontology-based cognitive assistance framework for ambient assisted living (AAL) systems, providing adaptive dialogue and assistance to individuals with

cognitive impairments. The model uses the speech acts theory for translating cognitive assistance into adaptive assistive messages. The model's usability and applicability are demonstrated via a real-life scenario, showcasing its effectiveness in providing graded guidance messages.

The authors in[81] examine the outcomes of rehabilitation using gait robot-assisted training in stroke patients with hemiplegia. The experimental group received stroke rehabilitation using gait robot-assisted training while the control group received conventional rehabilitation. The gait robot-assisted rehabilitation with goal setting improved stroke self-efficacy, balance ability, gait ability, and health-related quality of life in patients.

Rehabilitation for Neurological Disorders

Neurological disorder includes a wide range of disorders like brain tumor, head injury, epilepsy, syndrome disorder, etc. This section refers to the studies related to the rehabilitation of serious mental illness, vascular disorders, and depression/anxiety.

The methodology developed in[57] aims to improve CBT, especially for the treatment of depression by revealing the pattern of the brain under depression and by suggesting new ways to help people with depression through thinking and learning. It is a cross-sectional cohort study that reveals that understanding the association of RL with brain regions of people without depression can help improve CBT and also help clinicians treat people with depression. A study is presented in[82] to investigate the differences in RL parameters between patients with anxiety or depression and control individuals. Authors have also performed a novel simulation meta-analysis in parallel with the conventional meta-analysis. A sequence of random-effects meta-analyses are performed after the extraction of individual-level parameters to examine whether any of the most commonly reported parameters showed differences between control individuals and patients.

A recent study[83] considers the efficacy of Computerised Cognitive Training (CCT) on functional, psychosocial, mode, and cognitive outcomes and daily functioning in adults with depression. The authors investigated this in comparison with passive or active control. Moreover, the authors have examined the intervention design factors that may moderate CCT effects across each domain study. The quality and strength of the evidence for CCT in depression are also evaluated. The study[84] aimed to enhance functional outcomes in people having serious mental illness. Modern ICTs, like mobile apps, provide solutions for patients experiencing serious mental illness to improve functional outcomes. The program provides psychiatric rehabilitation to help patients improve their social and cognitive disabilities.

The work of[60] considers the cortical Striatal pathway for two common neurodevelopmental disorders. Differentiation between corticostriatal dysfunction in learning and attentional disorder has been studied through RL approaches by observing the cognitive processes involved. The whole study is observed in males only but the findings suggest the difference in patterns of learning disorder and attentional disorder for model-based RL and model-free RL. The efficacy of a computer-aided cognitive training program is investigated in[85] on depressive symptoms, behavioral symptoms, and cognitive measures in patients having major vascular neurocognitive disorder. The subjects were divided into a control and a treatment group, and all of them received a neuropsychiatric inventory, the Aasberg depression rating scale, the Montgomery, and the mini-mental state examination.

A review study[86] highlights ML approaches in post-stroke rehabilitation for functional recovery prediction and prognosis. Five electronic databases were investigated during the study. They extracted the validation approach, the algorithm used, the scheme for feature extraction and selection, outcome assessed, population characteristics, and health conditions. The research[58] is a telerehabilitation program for neurocognitive disorder patients. The research is a controlled trial that compares the Core and HomeCore programs, one for hospital trials and the second for distance treatment. The program provides a wide range of cognitive exercises like exercises for episodic long-term memory, executive functioning, working memory, attention, and processing speed.

A review of the applications of LEAP motion for various psychological domains, in particular, implementation and basis for interventions in neurocognitive and neurodevelopmental disorders are given in.[87] The survey work discussed studies on autism spectrum disorder and attention-deficit hyperactivity disorder as examples of neurodevelopmental disorders, and MCI, and dementia as examples of neurocognitive disorders. The study in[88] discusses the importance of cognitive rehabilitation in individuals with type 2 diabetes. It evaluates the effectiveness of a program called Memory,

Attention, and Problem-Solving Skills for Persons with Diabetes (MAPSS-DM) and aims to explore how it enhances cognitive functioning and diabetes management. The findings suggest that the intervention group showed improvement in memory and executive functioning with better diabetes self-management. The review work in[89] found that cognitive rehabilitation programs using cognitive training, compensatory strategies, or a combination of both can improve cognitive function for breast cancer survivors with chemotherapy-related cognitive impairment. However, a clear recommendation could not be established due to methodological concerns and varied program parameters. The research done in[90] focuses on improving cognitive rehabilitation for individuals with speech disorders through the use of machine learning. By combining the machine learning approach with data collected from the EEG and Kinect sensor, the model has achieved promising results for real-time scenarios and improved the overall quality of life.

The work in[91] analyzes the relationship between delirium, physical exercise, and rehabilitation. There is a strong connection between delirium and physical functioning. Delirium affects cognitive and motor functions, so the motor component of delirium should also be considered when designing inter- ventions or strategies. In,[92] a digital intervention was tested in adult patients with major depressive disorder and cognitive impairment. Improvement in sustained attention was observed with AKL-T03 compared to the control intervention. Further research is needed to understand the clinical consequences and impact of AKL-T03.

The study in[93] aims to investigate the effectiveness of a new exergame-based motor-cognitive training called "Brain-IT" in enhancing cognitive functioning in older adults with the mild neurocognitive disorder (mNCD). The main measure of outcome is overall cognitive functioning, with additional measurements like brain structure and function, gait parameters, and daily activities.

Rehabilitation for Developmental Disorders

Developmental disorder refers to the incomplete development of a child's behavior, mind, and language. A lot of disorders like autism spectrum disorder, and all kinds of learning disorder comes under developmental disorder. The successful treatment intervention is therapy (both cognitive and behavioral), the earlier it begins, the sooner the child will become independent. This section contains different AI-based treatment interventions for children with developmental disorders.

Neurodevelopmental disorder interventions are better treated with single-case experimental designs (SCEDs). In[59] following SCED, two children one with autism spectrum disorder and the second with agenesis of Corpus Callosum have been studied using BEHAVE application for manding repertoire. BEHAVE application proves its effectiveness as a tool in collecting and analyzing data, and also in evaluating the frequency of independent minds performed by case studies. Intellectual development disability (IDD) affects cognitive functioning as well as causes learning and social impairment in children. In,[62] the authors investigate the effects of CCT on intellectual and adaptive functioning in developmentally disordered children. The study investigates the effects of CCT in 4 cognitive domains ie learning, reasoning, working memory, and visual perception. The results imply that CCT raised the kids' IQs by enhancing both their intellectual and adaptive functioning.

Dyslexia is another developmental disorder that limits the learning abilities of children[63] proposes an adaptive framework (RALF) for helping children with dyslexia. RALF is designed to generate short- and long-term content for training students incorporating the Cellular Learning Automata (CLA) structure. Experimental application of RALF and its comparison with a control group indicated no significant overall achievement, but as a part, the reading abilities of dyslexic students improved by using this framework.

The authors in[94] employed a randomized controlled model to perform a comparison of the training outcomes between remotely delivered neurofeedback, Computerized Cognitive Training (CCT), and combined neurofeedback/CCT training schemes. They randomly assigned 121 children with attention-deficit/hyperactivity disorder to the above three groups. The authors observed a significant improvement in the life skills, learning, working memory, inhibition, and the inattentive and hyperactive/impulsive symptoms of the 3 groups of children after three months of training. Moreover, the authors verified the training effects of neurofeedback, CCT, and combined neurofeedback/CCT training in children with attention- deficit/hyperactivity disorder. Children with autism spectrum disorder face learning difficulties along with memory issues. In,[61] the authors have introduced an intelligent tutoring system namely RELETAS, to help children with ASD to fight learning disorders by using RL. RELETAS is based upon ANN and RL and is designed to enhance the

working memory of the children along with Zone of Proximal Distribution (ZPD), although the evaluation is done only in a single concept and the RL agent achieved a reward by answering 1000 correct answers out of 10,000 questions. The study in[95] was to evaluate how the cognitive enhancement training (COGENT) program impacted the reading and writing abilities of students with specific learning disabilities (SLD). The results showed that the COGENT program had a positive effect on reading speed, reading comprehension, and dictation skills among the treatment-group but no considerable difference in text copying. Feedback from teachers revealed that they observed improvements in the literacy skills of students as well as some social skills.

An evaluation on the effectiveness of telerehabilitation for learning disabilities in adolescents during the COVID-19 lockdown is done in.[96] Twenty-four adolescents received cognitive treatment via a telehealth app for four weeks, leading to significant improvement in cognitive domains such as attention, memory, and information processing speed. Telerehabilitation can improve cognitive functioning in patients with learning disabilities and promote healthcare at home. This study[97] tested the usability of telerehabilitation on reading and writing in children with Specific Learning Disabilities (SLD). Results indicate notable improvements in executive functions, text dictation, and reading fluency in the telerehabilitation group. Children participating in a combined training program showed improvements in word reading fluency and text dictation. These findings have important implications for clinical research and practice in the field of telerehabilitation for children with SLD.

Virtual Reality-Based Rehabilitation

This section focuses on showcasing a wide range of virtual reality (VR) therapies, intended to improve the cognitive performance of older persons. The therapeutic applications of VR are wider than anything as it provides personalized interventions, simulates real-life events, improves attention and concentration, provides exergaming at home, and much more. The human empowerment aging and disability VR protocol is explored in[98] and found suitable in clinical and at-home telerehabilitation for patients in the chronic stage after stroke. The method is helpful in the continuity of care as it is effective at home in long-term maintenance and augmenting motor and cognitive abilities in the clinic. An immersive on-body feedback system using an iterative user-centered design process is developed in[67] to conserve the advantages of the physically immersive setup of the ExerCube to be used at the home. The proposed system can evaluate the feasibility and training experience of the home-based exergame as well as its beginning-stage on-body feedback system.

The use of digital technologies, like AI, advanced data analytics, VR, IoT, and game-based learning are discussed in.[99] In the development of innovative rehabilitation techniques, in particular for mental health rehabilitation in people diagnosed with schizophrenia spectrum. Moreover, the authors proposed a VR serious game as an auxiliary solution for rehabilitation. It assists three forms of users including the medical team, the caregiver, and the patient. The work of[100] focuses on developing and validating VR applications for the diagnosis and treatment of neurocognitive conditions including Alzheimer's Disease. The goal here is to enhance the effectiveness of rehabilitation through the use of VR technology. The dynamics, features, architecture, and usability of the system are all customized to meet the requirements of the patient. The project investigates the existing and future applications of VR in the treatment of neurocognitive diseases. The potential use of therapeutic applications of VR is discussed in.[101] These applications employed biofeedback designed along with massive virtual spaces to assist in breaking perpetual cycles of insomnia, anxiety, and depression. The VRs can take the shape of a fantastical cosmic scene, mountain tops, or a night sky. The authors also discuss the use of perceived massive spaces for therapy and the spatial foundation of the mind in virtual therapies[66] discusses two cognitive interventions and their effects on people with mental and behavioral disorders. Caˆmara et al have tried Reh@City and Task Generator and the assessment results revealed that the Reh@City v2.0 program caused a significant reduction in depressive symptoms, whereas the TG program improved memory, processing speed, and social behavior of patients, hence leading them towards a quality life.

The use of telerehabilitation can be an innovative method to promote physical activity and implement home-based rehabilitation to provide rehabilitative therapy to individuals with physical, cognitive, or functional limitations. The[102] evaluates the feasibility, enjoyment, and potential effect of telerehabilitation using a serious game' MoveHero' for people with ASD during the COVID-19 pandemic. All participants participated in telerehabilitation sessions with full adherence and there was a significant improvement in the performance of the non-ASD group at most moments. The findings support using gaming interventions and serious games to get people with ASD to be more active.

The authors of[103] assessed the feasibility of non-immersive VR training for relearning functional living skills in patients with major neurocognitive disorders. The results showed significant improvement in all VR training variable scores for both EG with degenerative conditions and EG with non-degenerative conditions (NDC), with better outcomes in the EG-NDC group. The study confirmed the ecological validity of VR training for functional living skills. The work in[104] aims to determine if combining RL-based virtual AI assistant with play therapy can improve physical activities like muscle reflexes, motor controls, and hand-eye coordination in wheelchair-bound children with Down syndrome. The AI assistant is designed to learn how a patient plays the game and provide challenges that are tailored to their specific abilities. The findings suggest that the agent trained with the PPO algorithm and Actor-Critic algorithm together outperforms other algorithms by being a powerful AI virtual assistant that can compete against a player with Down syndrome and help them enhance their skills as well as weaknesses.

In,[105] a VR rehabilitation environment for the sake of stroke survivors has been discussed. VIRTUE application uses Unity3D along with VR Toolkit (VRTK) to enhance motivation in stroke survivor patients and help them re-learn their daily life activities. The successful deployment of VIRTUE in a hospital indicates that it is safe and acceptable for cognitive rehabilitation of stroke survivors under the supervision of occupational therapists. The study in[106] evaluates the effectiveness of the VR platform namely Reh@city. Reh@City v2.0 was used in a randomized controlled trial on 36 chronic stroke patients. The results showed an improvement in over- all visuospatial ability, attention, executive functions, cognitive functioning, processing speed, verbal memory, and self-perceived cognitive deficits. The group that used Reh@City demonstrated superior performance in general cognitive functioning, visuospatial ability, and executive functions when compared to the control group.

The authors in[107] evaluate the usability of non-immersive VR training on functional living skills in patients suffering from major neurocognitive disorders. The experimental group (EG) and control group (CG) were subjected to in vivo tests, and statistically significant differences were observed between them. The improvement in in vivo tests was found to be associated with the specific VRT utilized. A cognitive rehabilitation program based on self-efficacy theory was developed in[108] using virtual reality technology and compared to conventional and computer-assisted cognitive rehabilitation. The study found significant differences in stroke self-efficacy, cognitive function, and health-related quality of life after implementing the virtual reality-based program. Significant group differences were observed among the groups specifically in self-efficacy and health-related quality of life.

In,[109] the authors examined the impact of immersive VR on predementia individuals. Both control and experimental groups were evaluated for cognitive functioning and visual brain network connectivity. The study indicates that immersive VR cognitive training may enhance visuospatial functioning and alleviate psychiatric symptoms in predementia individuals.

Rehabilitation of Neurodegenerative Diseases

Neurodegenerative diseases refer to the gradual dysfunction of the brain with some of its parts damaged. The process is incurable however AI-based interventions have tended to delay the process successfully. Among all neurodegenerative diseases, the most common types are dementia, Alzheimer's disease (AD), Parkinson's disease, Huntington's disease, etc. The study in[110] is a meta-analysis to review the effectiveness of cognitive rehabilitation in non-demented Parkinson's disease (PD) patients and findings revealed that commonly improved cognitive domains were attention, memory, and processing speed. However, further studies are necessary to determine more robust effects. The work in[111] discusses the effectiveness of telephone-based reality orientation therapy (ROT) for dementia patients. The study found that implementing the ROT intervention resulted in significant improvements in patients' understanding and sense of control over their surroundings. Furthermore, it was found to be effective for caregivers, as it helped to reduce their burden and stress levels. A systematic review[22] analyzes the use of wearable devices in patients with Parkinson's disease (PD) and neurocognitive disorders. The findings suggest that sensor-based wearable devices, particularly instrumented insoles, play a crucial role in monitoring, diagnosing, and tracking exercise for PD and neurocognitive patients. These wearables can help in improving early diagnosis, rehabilitation, and overall quality of life among PD patients.

The authors in[112] analyzed that cognitive telerehabilitation improved cognition, neuropsychiatric symptoms, and memory strategies in patients with mild cognitive impairment. Results of the post-test showed that the treatment group had better scores in cognitive variables and experienced a reduction in affective symptomatology concluding that cognitive telerehabilitation is an effective intervention for mild cognitive impairment. The study of[113] reviews cognitive

rehabilitation for mild-to-moderate dementia and it found that cognitive rehabilitation improved self-efficacy, quality of life, and cognition in people with dementia and their care partners. However, there was insufficient evidence to determine whether it had any significant benefits for caregivers in reducing anxiety.

The work in[64] is about creating and validating an AI model tailored to address cognitive impairment in dementia. The model utilized the RNN framework to forecast MMSE and MoCA scores following drug initiation. Notably, patients who received the drug recommended by the AI model exhibited enhanced cognitive performance. These findings underscore the potential for AI-informed personalized treatment to enhance cognitive outcomes in patients with dementia. In,[65] the authors assess the efficacy of the cognitive rehabilitation program "GRADIOR" in individuals experiencing MCI and mild dementia. Results showed that the experimental group maintained cognitive functions with moderate to large effect sizes while the control group exhibited more decline even after a year. Using GRADIOR for longer periods may benefit people with mild cognitive impairment and mild dementia.

The research done in[114] provides a comprehensive overview of how intelligent technologies can be used in clinical practice, specifically for Alzheimer's disease. It discusses the potential benefits of these technologies and highlights areas in which their design can be improved. The study aims to provide a better understanding of the role of sensing technologies throughout the progression of the disease and identify research gaps. In,[115] researchers aimed to investigate the effectiveness of a stepping exergame program in individuals with major neurocognitive disorders. The study evaluated outcomes such as gait speed, balance, reaction time, cognitive and neuropsychiatric measures, and daily life functioning. The exergaming program demonstrated significant reductions in depression when compared to the control group.

In,[116] various factors are investigated that influence people with MCI and mild dementia following a CCT program. The GRADIOR program encompasses a wide array of exercises targeting orientation, memory, attention, perception, and executive functioning employing a user-friendly interface. The study aimed to identify cognitive, psychological, and physical health factors that adhere to the CCT program. The study in[117] is about determining the effectiveness of an online CCT platform VIRTRAEL for clinical purposes. VIRTRAEL is designed to improve different cognitive skills in older adults with MCI. The post-test showed greater improvement in verbal learning, delayed recall, working memory, reasoning, and planning indicating that VIRTRAEL can be an effective tool in addressing cognitive symptoms associated with aging and neurodegenerative diseases.

The study in[118] examined the effect of an Occupational Therapy program on the independence of older adults. The program was based on activities of daily living (ADL) cognitive stimulation. The results showed that the cognitive stimulation program helped participants to perform ADLs independently suggesting that it can help increase the independence of individuals with dementia. The article[119] reviewed eight trials evaluating exergames for individuals with major neurocognitive disorders. The study found that exergames have physical and mental benefits, such as improving gait, mobility, balance, cognitive function, and quality of life. However, more controlled trials are necessary before exergames can be recommended for treatment guidelines. The objective of the study[120] is to compare the efficacy of computerized training with web-based cognitive games and web-based crossword puzzles in patients with MCI. The study had a diverse sample, rigorous methodology, and a long study duration. Improvement in the ADAS-Cog score was observed in both groups, but the percentage of improvement was higher in the crossword group.

Telerehabilitation of Cardiovascular and Other Diseases

Telerehabilitation (TR) is the delivery of rehabilitation services through technology. Over the past few years, due to the advances in AI technologies and telemedical devices, telemedicine has gained a lot of attention. Long-distance communication can now be easily achieved through various means like videoconferencing, email, phone call and texting. This section contains telerehabilitation-based interventions for various diseases like cardiovascular, stroke survivors and cancer survivors.

The article[121] emphasizes the necessity of performing clinical feasibility assessments of telehealth interventions, for cancer survivors in order to scrutinize effectiveness, safety, compliance, and user contentment of the intervention. The findings reveal the presence of obesity, depression and smoking in the patients which can be managed by conducting physical and telehealth exercises for each patient. In article[122] researchers have highlighted the safety and impact of a home-based cardio-oncology rehabilitation (CORE) intervention utilizing a telerehabilitation among individuals who have survived hematological cancer. The approach encompassed three components: a sensor to measure heart rate, an

internet platform, and remote supervision through telephone communication. The findings reveal that the participants experienced a noteworthy improvement in their cardiorespiratory fitness and maximum workload.

In[123] Blioumpa et al conducted a telerehabilitation-based intervention for patients of type 2 diabetes. The intervention included exercise sessions through videoconferencing to enhance the functional capacity, regulation of blood sugar (HbA1c), quality of life and awareness of self-management in type 2 diabetes patients[124] is a review article evaluating the effectiveness of wearable sensors in home-based cardiac rehab (HBCR) intervention for patients of cardiovascular diseases (CVD). The meta analysis reveals that wearable technology for the assistance of HBCR has the potential to replace center-based cardiac rehabilitation as it has improved the overall health profile of a patient with CVD. The review article[125] evaluates the effects of telerehabilitation in chronic obstructive pulmonary disease (COPD) patients as compared to conventional interventions. The review suggests that telerehabilitation is safe and sound approach with noticeable diversity.

In a pandemic like COVID-19 researchers find out the need of telerehabilitation for the patients to perform their rehabilitation tasks. Article[126] aims to do the same, by developing a telerehabilitation platform for the individuals having a problem of "range of motion" (ROM). The results reveal the positive impact of real-time tracking of exercises and overall approach on patients. In article[127] researchers have developed a machine learning-based rehabilitation system to be practised at homes for stroke survivors. The study suggests that a home care system using a commercial smartwatch and ML model can improve ROM in stroke survivors. In,[128] Garzo et al describes the telerehabilitation platform namely ArmAssist (AA) developed to help patients of stroke. With the help of healthcare professionals, the following approach includes arm and hand exercises for the individuals. The training involves some serious games suggested by professionals while the evaluation has been done by standard clinical tests. Another telerehabilitation platform MediaPipe is discussed in article.[10] MediaPipe is a website used for rehabilitation of ROM and knee fracture monitoring of patients. The primary focus of MediaPipe is to provide patients necessary facilities in the comfort of their homes. The reliability and validity of the platform are measured by real cases.

Statistics and Impact

Statistics analysis are important and help to quickly identify major information of the underlying topic. Therefore, in this section, we perform an analysis of the studies that we have discussed in section IV.

Publication type is an important aspect of any research work. Among, type of publication, the journal publication are considered better than the other types of publication. In Figure 5, we presented the number of papers that have been published in conferences and journals. Similarly, we highlighted the distribution of the papers in Figure 6. Both charts show that most of the cited papers are the journal papers and the distribution for studies belonging to book chapters, conferences, and journals are 0%, 8.4% and 91.6%, respectively. Figure 6 presents that this study is mostly based on the recent journal publications in the diverse areas and it highlights the impact of AI methods in Rehabilitation process. As this work primarily focuses on the use of AI methods in the various rehabilitation process. Therefore, it is important to know the use of each AI tool separately. We present the number of applications of each AI method and corresponding distribution in Figures 7 and 8 respectively.

It is also important to statistically analyze all the rehabilitation processes that we considered in the section IV. Figure 9 shows number of papers belong to each category while Figure 10 shows the distribution of each category. It is evident from Figure 10 we considered almost all areas equally. Moreover, we can observe that ICT is contributing in many important and diverse processes of Rehabilitation.

Furthermore, we can verify recent progress of AI and ML methods in various aspects of rehabilitation by analyzing the research work in most recent years. Therefore, we highlight the number of papers and their corresponding distribution for the years from 2020 to 2023 in Figures 11 and 12 respectively. We can quickly identify that the use of AI and ICT in rehabilitation processes has been continuously increasing over the past years. A thorough survey of the literature is very important for all research fields, and it helps the research community in identifying recent advances in the specific research direction. Similarly, there are many sub fields of a general research area like we discussed different rehabilitation process in section IV. So it is worthy to know the top cited works of each research area. To provide, such a quick and valuable information, we highlight in Table 3 the top five most cited studies against each rehabilitation process that we considered in Section IV. The column 1 indicates to the rehabilitation process and columns 2 to 6 refer to the reference of the top cited
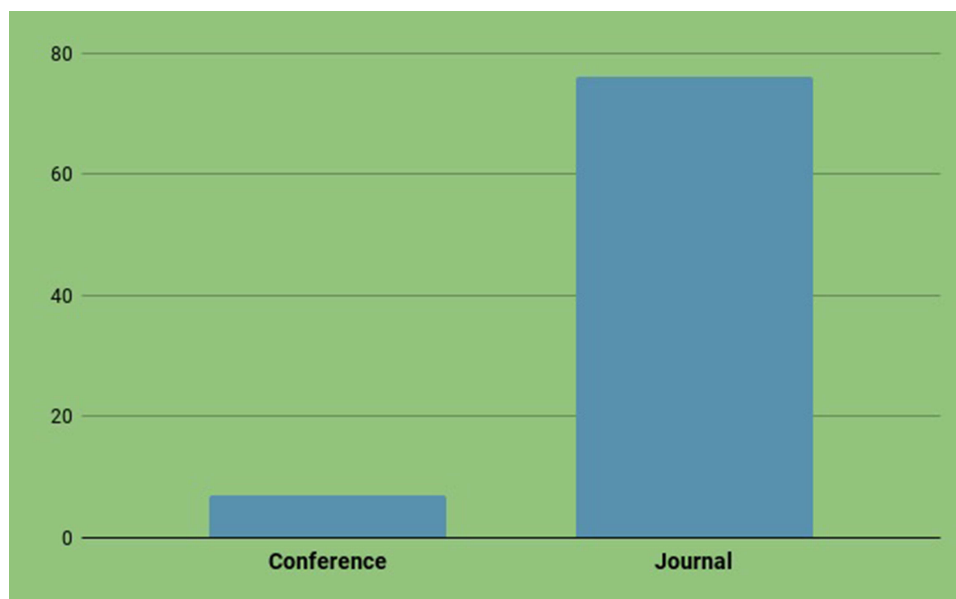
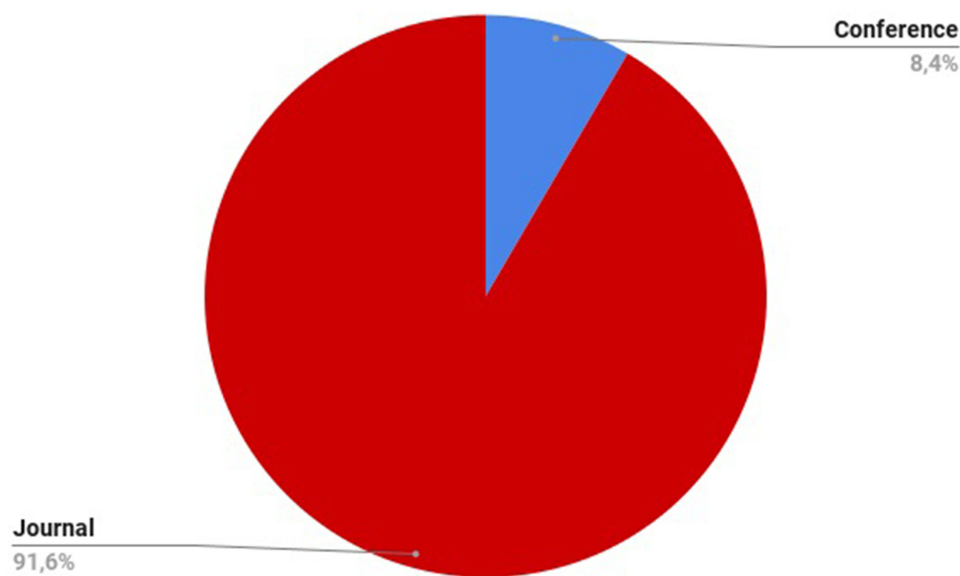**Figure 5** Number of the papers according to their category.

Figure 6 Percentage distribution of journal, conference, and book chapters publications.

studies. For instance, the five most cited papers in the applications of AI in the category of' Rehabilitation Apps' in descending order are.[51,53,69,75,76] Similarly, top-cited articles for Rehabilitation via Assistance, Rehabilitation for Neurological Disorders, Rehabilitation for Developmental Disorders, VR-based Rehabilitation, Rehabilitation of Neurodegenerative Diseases and Telerehabilitation of Cardiovascular & Other Diseases are[22,54,57,106,129] and[127] respectively.

Discussion and Future Challenges

In this section, we summarize this study as well as discuss some challenges and future directions.

This review work discloses the state of the art on AI-powered methods providing cognitive stimulation, and rehabilitation for young and older adults. The study objective is to evaluate the characteristics of AI-based programs
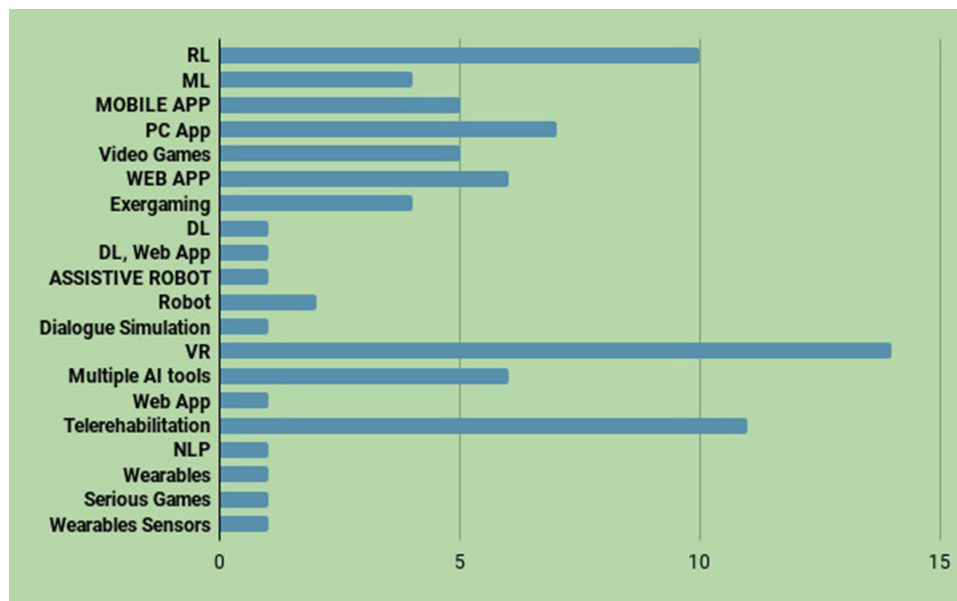
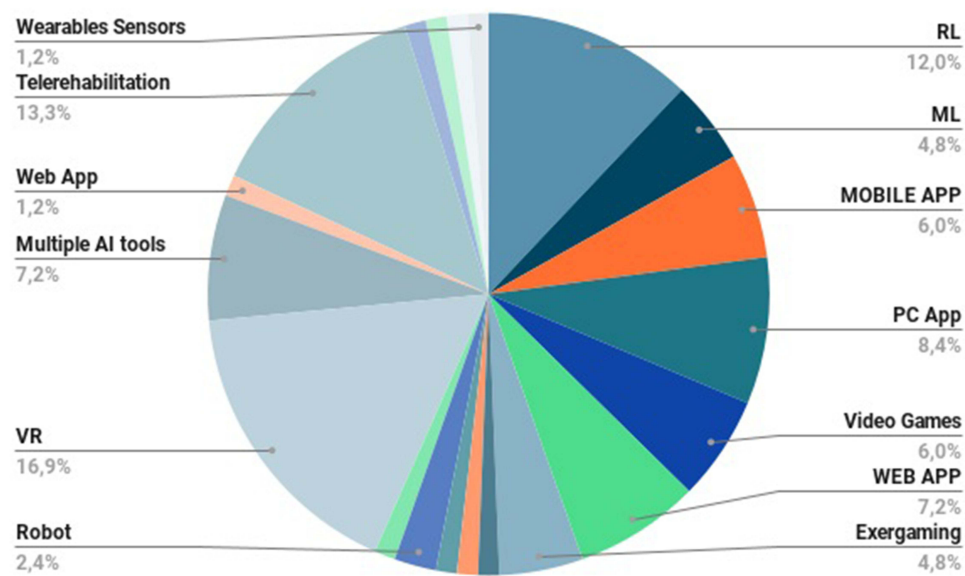**Figure 7** Number of AI-based techniques for different Rehabilitation Process.

Figure 8 Distribution of surveyed AI-based techniques.

and the similarities and differences between the existing ML software, avoiding considering that all AI-enabled programs working for the rehabilitation process are identical. We divided AI-enabled techniques used for the rehabilitation process into seven different groups including Personalized rehabilitation Apps, Rehabilitation through Assistance, Rehabilitation for Neurological Disorders, Rehabilitation for Developmental Disorders, Rehabilitation for Neurodegenerative Diseases and Telerehabilitation of Cardiovascular & Other Diseases.

The study highlights that AI programs with standardized training sessions are not adaptable for treatments to the cognitive profile of patients. This is a considerable disadvantage as the training is identical for all, although the difficulty level of the exercise varies. It is also noted that a few programs can propose exercises of the most suitable cognitive difficulty level automatically. The software features can have both advantages and disadvantages as well. It also depends
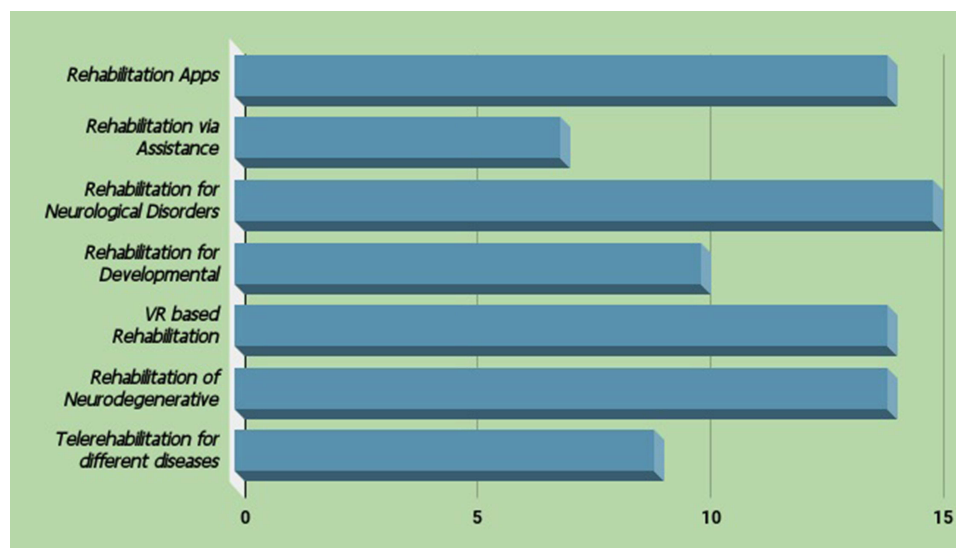
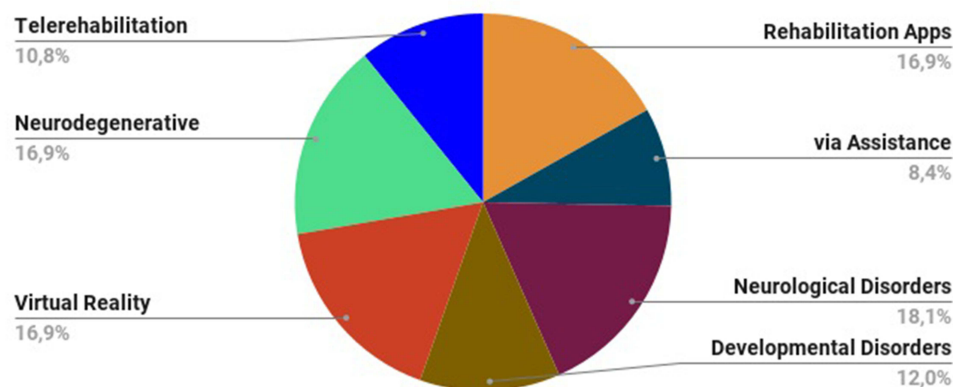**Figure 9** Number of articles surveyed for each category.

Figure 10 Distribution of surveyed articles for all categories.

on the use and the characteristics of every individual, one AI program may be more appropriate than another. In our analysis, web-based software operating through an internet connection can enable the implementation of the intervention as it could be installed on any machine having an internet connection and will function remotely.

Moreover, the design and implementation of ML algorithms for neurodegenerative disease data remain hard. One apparent challenge is related to the data itself as ML models are as powerful depending on the data used for model training. A barrier to the application of ML for many diseases is the lack of large data sets, in particular, multi-dimensional patient data. Because such data sets normally contain data from hundreds of patients and may be noisy due to inconsistent measurement, participants drop-out. Metadata analyses can be useful as the overlap between results obtained from different datasets may be small. Therefore, metadata analyses can detect inconsistencies across datasets and enhance the statistical power of the data.[18] Sometimes data are also biased towards specific demographic popula-tions, which often limits the learning generalization and there may be a disparity in healthcare.[130] Similarly, new ML methods like active learning techniques can be employed to mitigate the issue of small data sets. Active learning methods enable quality inferences from a few samples compared to ML strategies and eliminate the need to label large datasets, which can be expensive.[18]

The use of virtual reality for cognitive rehabilitation is increasing. Therefore, there is a need to conduct studies and research efforts focusing on the efficiency, effectiveness, validity, and reliability to validate existing VR schemes.[131]
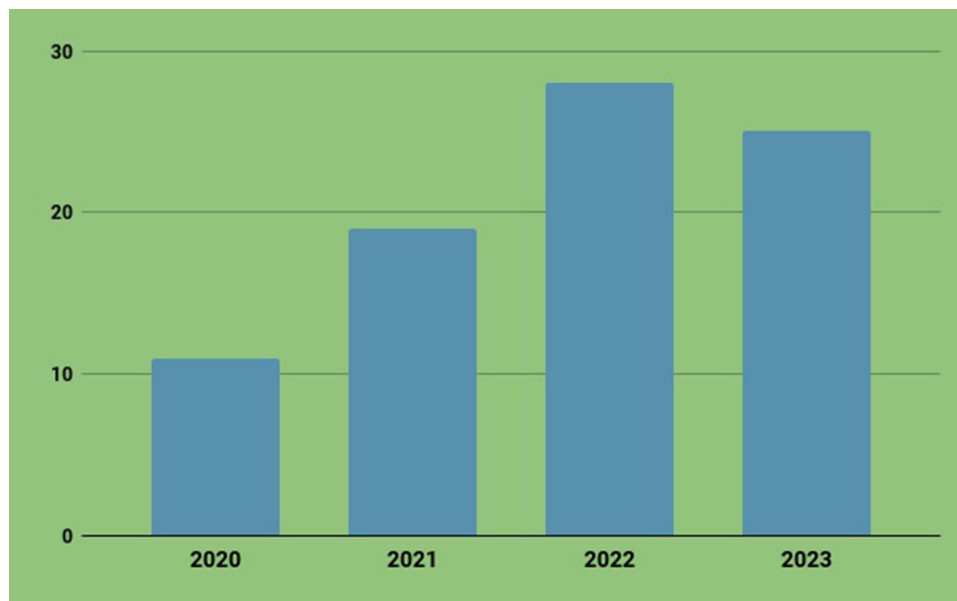
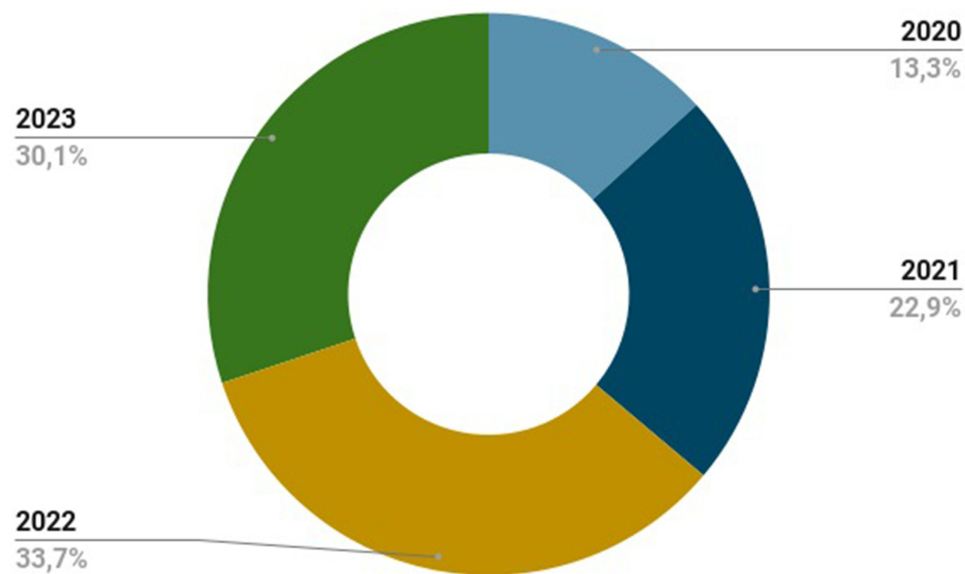**Figure 11** Number of surveyed articles published from 2020 to 2023.

Figure 12 Distribution of surveyed articles for years 2020 to 2023.

Additionally, telerehabilitation and VR methods have no precise effect on a single realm, instead, plan to stimulate multiple domains simultaneously to obtain a higher degree of ecological validity.[132] The design and modeling of specific VR approaches comparable with conventional techniques may provide challenging options for future research. Another issue with VR therapy is the limitation of clinical training that hampers its diffusion[133] and this issue could be addressed by training some health professionals like neuropsychologists.

Some traditional examination tests concerning rehabilitation to monitor gait deflation are time-consuming and dependent on task performance, and multiple parameters such as incapability to complete due to fatigue, physical exertion by the participant, the complexity of the task assigned to the patient and walking area may affect the results.[22] The AI-based wearable devices can assist in rehabilitation exercises as well as in analyzing the disease evolution.

Table 3 Left To Right In Descending Order:First Five Most Cited Studies From Each Rehabilitation Type

Category	Paper-1	Paper-2	Paper-3	Paper-4	Paper-5
Rehabilitation Apps	[76]	[69]	[53]	[51]	[75]
Rehabilitation via Assistance	[54]	[79]	[80]	[55]	[56]
Rehabilitation for Neurological Disorders	[57]	[82]	[91]	[86]	[87]
Rehabilitation for Developmental Disorders	[129]	[96]	[94]	[63]	[61]
VR based Rehabilitation	[106]	[98]	[109]	[105]	[100]
Rehabilitation of Neurodegenerative Diseases	[22]	[113]	[110]	[111]	[114]
Telerehabilitation of Cardiovascular & Other Diseases	[127]	[124]	[10]	[121]	[126]

However, it should be noted that significant research is still required for wearable solutions on the reliability, precision, accuracy, and objective support of healthcare systems and patients for validation and adoption. Finally, we should agree that AI tools are already integrated into our healthcare setup and will continue to improve its applications in health-related aspects. Similarly for rehabilitation, AI is being employed for personalized treatment regimens, injury prevention, remote rehabilitation, patient monitoring, and the automation of many rehabilitation tasks. These technologies offer efficiency for practitioners, improve patient rehabilitation process, and enhance care access. However, legal implications like data protection and privacy are still a concern. Moreover, the potential negative impact of less human interaction with the use of AI is another concern that need to be considered. These challenges demand for more education, continued research, and additional legal considerations to adequately integrate the use of AI in order to provide benefits to practitioners and patients and to decrease the possible unintended negative consequences.

Conclusions

The need for rehabilitation globally is expected to increase according to WHO due to changes in the characteristics and health of the population. Keeping in view this importance, this study reviewed the recent impacts of AI technology on the rehabilitation process. We investigated AI's role in the diverse aspects of the rehabilitation process, like personalized rehabilitation apps, rehabilitation through assistance, rehabilitation for neurological disorders, rehabilitation for developmental disorders, virtual reality rehabilitation, rehabilitation of neurodegenerative diseases and Telerehabilitation of Cardiovascular. Similarly, we highlighted the increasing use of AI for the rehabilitation process using statistical analysis. In the end, we briefly outlined some challenges regarding AI technology integration into rehabilitation processes. Future research perspectives should include both assessment and rehabilitation processes among neurological populations. Thus, AI-based technology and RL setups may be firstly implemented to differentiate between a normal/typical cognitive development and a risk of pathology. Secondly, technology- aided options may be considered in the recovery process of cognitive functions. Furthermore, one might differentiate cognitive processes (eg, attention, memory, and language). Finally, one can envisage the use of AI app and RL to investigate also emotional processes and differentiate between a typical emotional competence and/or personality disorders.

Disclosure

The authors report no conflicts of interest in this work.

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