**Robotics for Neurorehabilitation of neurodegenerative diseases**

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**Abstract**

Crippling diseases of the nervous system place great burdens on health and social life for people around the world. Neurodegeneration is a major factor and is often the cause of disability in many diseases that are rarely considered impaired - for example, multiple sclerosis, epilepsy, congenital metabolic disorders, schizophrenia, and even tissue. Neurological degenerative diseases have a significant impact on the technical, communal and family status of patients and can lead to absolute failure of any type of daily activity. Rehabilitation is an effective and powerful process in which a person with a disability is helped to obtain knowledge and skills to enhance their physical, mental and communal functioning. The interaction between the human mind and the physical realities has been shown to enhance cognitive functions. Biologically, this effect cannot be achieved without the action of other types of neural plasticity, such as strengthening or reducing the strength of synaptic transmission, remodeling of synaptic connections, reconstruction of dendritic nerves, reorganization of neuronal morphology, or mutation of electrical pleasure. Direct evidence of basic cellular changes at the level of individual neurons, however, is beyond the reach of current thinking patterns of active brain. This review is done to evaluate that robotics is evident in neurodegenerative diseases for the specific disabilities.

# Keywords: Parkinson's disease (PD), Alzheimer's disease (AD), Amyotrophic lateral sclerosis (ALS), Robotics, Artificial intelligence and Neuroplasticity

1. **I****NTRODUCTION**

Crippling diseases of the nervous system place great burdens on health and social life for people around the entire world. Parkinson's disease (PD), Alzheimer's disease (AD), and amyotrophic lateral sclerosis (ALS) are the three major neurodegenerative diseases. The incidence and outbreak of these diseases are greatly exacerbated by aging; therefore, the number of cases is expected to elevate in the inevitable future as life expectancy in many countries continues to increase[1].

Neurological degeneration is a major factor and is often the cause of disability in many diseases that are rarely considered impaired - for example, multiple sclerosis, epilepsy, congenital metabolic disorders, schizophrenia, and even tissue[2].

Neurological degenerative diseases are caused by a gradual decrease and / or death of neurons (cells responsible for the functioning of the nervous system). This decline can affect physical activity and brain function, leading to dementia (continuous or continuous reduction in cognitive function that affects some aspects of memory, reasoning/thinking, behavior, speech/language, counting, learning and emotional abilities, and should never be associated with normal aging process)[3].

These diseases/disorders are one of the major medical, social and economic problems of our time, affecting people of all ages. The causes of their appearance are unknown; they can be a variety of diseases: Alzheimer's Disease (AD); Parkinson's disease (PD); Amyotrophic Lateral Sclerosis (ALS); Multiple Sclerosis (MS); Huntington's disease (HD); Machado-Joseph's Disease; Family of Amyloid Polyneuropathy, better known, Alzheimer's disease and Parkinson's.

Neurological degenerative diseases have a significant impression on the technical, social and family status of patients and can lead to total failure of any type of daily activity. For example, patients may have: motor problems; difficulty in breathing due to involvement of respiratory muscles; cognitive issues or memory loss gradually (which may affect the memory of all that has been learned over a lifetime)[4].

Neurological rehabilitation is primarily about paralysis. Rehabilitation is an effective and powerful process in which a person with a disability is helped to gain knowledge and skills to enhance their mental, physical and social functioning. This process can be reduced to three key areas:

1. Ways to decrease motor disability

2. Strategies designed to learn new skills and strategies, which will increase performance

3. Strategies that help to change the environment of patient, both physical surroundings and social influences, so that a given disability can be accompanied by less disability[5].

The renewal process is set in goal setting. The first and foremost goal to be set is the long-term achievement of the plans. For many the long-term goal could be to return to a normal life. For some, it may simply be to return home and stay at home with the help of caregivers. Once a long-term goal is achievable and achievable then small steps are needed to achieve that goal. If, for example, the long-term goal is to move in a particular environment independently without the use of resources, attaining that goal may be out of reach for many short-term goals[6]. This process, for example, can start with living without support, and then stop without any support, and then go with the help of a person, then go through resources, and lastly achieve the attainment of independence. Objectives should be straightforward. There is no basis for setting clear and unambiguous goals as a correctional team or person with a disability will not be able to monitor their status[7].

What it means to set realistic goals is that both the individuals with a disability and the rehabilitation team must know when the goals have been achieved. Therefore, it is equally essential for each target to have a valid and reliable outcome measure. There are a number of measures which are formulated to supervise disability and / or quality of life that can be helpful in assessing progress towards a long-term goal. Short-term goals often require particular outcome measures. Some of these steps need to be simplified and fast. In terms of rental accommodation, the simplest, fastest and most reliable route can be set to travel more than 10 meters. It is important to remember that any measure of the results used must be clear, effective, and reliable otherwise we should not use them. It is also worth remembering that while objective measurement is important, a person with a disability perspective on progress towards goal-oriented interventions can help rehabilitate patients with non-neurodegenerative diseases, and can be an important ingredient in replacing lost brain functions - computerized (BCI) interface that controls robotic devices[8].

The interaction between the human mind and the physical realities has been shown to enhance cognitive functions. Biologically, this effect cannot be achieved without the action of other types of neural plasticity, such as strengthening or reducing the strength of synaptic transmission, remodeling of synaptic connections, reconstruction of dendritic nerves, reorganization of neuronal morphology, or mutation of electrical pleasure. Direct evidence of basic cellular changes at the level of individual neurons, however, is beyond the reach of current thinking patterns of active brain. However, magnetoencephalography (MEG), electroencephalography (EEG), positron emission tomography (PET), near-infrared spectroscopy (NIRS), and imaging resonance imaging (MRI) can resolve an active brain condition with a macroscopic solution (e.g., EEG has a millisecond interim resolution and MRI has a localized millimeter resolution) that may experience additional changes in brain volume or excitement experienced within a few weeks of training or rehabilitation[9]. In this present review we will describe how robotics can help in neurorehabilitation of neurodegenerative diseases – amyotrophic lateral sclerosis (ALS), Alzheimer's disease (AD), and Parkinson's disease (PD).

1. **Alzheimer’s disease**

Alzheimer's disease (AD) is a prevailing cause of dementia. There is no prescriptive drug that will help to stop the flow of emotions, though their effects can be truncated. There are currently no specific symptoms that could confirm a 100% accurate diagnosis of AD.

Alzheimer's disease (AD) is determined by a progressive decrease in brain function. AD has increased dramatically in people 65 years of age or older, with a progressive decline in memory, thinking, language and learning ability. AD should be distinguished from the general age-related decline in cognitive function, which is slow and associated with minimal disability. Diseases often begin with minor symptoms and end with severe brain damage. People with dementia lose their skills at different rates[10].

Alzheimer's disease is a progressive degenerative disease that becomes worse over a span of time, causing problems with short term, long term and immediate memory, thinking/ reasoning and social behavior. It can be divided into three categories: -

In the middle of this stage, the most notable failure is memory loss, which greatly affects temporary memory (difficulty to recall newly learned gospel and retrieve new information). Moderate In this stage the patient becomes unable to perform most common activities of daily living. Severe During the final stage of AD, the person is completely dependent upon caregivers[11].

Robot investigative projects have tried to help patients who are affected with degenerative diseases and caregivers. A latest type of robot is determined: Socially Assistive Robot (SAR.). SAR. is defined by Tapus et al. in 2005 as a merger of Assistive Robotics (AR) which helped in the assistance for ADLs and Socially Interactive Robotic (SIR) which helped in the non-motor disabilities[12].

# Electronics | Free Full-Text | Socially Assistive Robots for Older Adults and People with Autism: An Overview

# Figure 1: (SAR) Rudy in a pilot study – (Martinez-Martin, E.; Escalona, F.; Cazorla, M. Socially Assistive Robots for Older Adults and People with Autism: An Overview. *Electronics* 2020, *9*, 367. https://doi.org/10.3390/electronics9020367)

Therefore, SARs. are outlined to provide aid to human clients through social media. SARs have already been used to design treatments for patients/clients with dementia (including AD). The previous studies describe [6,7], show that utilization of biomimetic robotic system, some patients/clients have deliberately improved their attention aspect in a span, their function of cortex, their emotions like depression, anxiety and their ability to overcome stress. In addition, patients needed some administration while communicating with the robot and, as a result, their caregivers also reduced their level of stress[13].

Many researchers are studying the relationship or intimation between robots and older people. Further, some of older people have focused or given their attention towards proper appearance or the image of a robot that communicates with adults. UWu et al. examined how older people recognize robots in relation to the appearance or image of robots. At the start of the research, individuals discussed their first robotic concept. Afterward, they were shown a presentation featuring 26 (twenty-six) different robotic images which were displayed on the screen along with a short video featuring active robots. In the end, each individual chose 3 favorite robots[14]. The results showed that individuals often chose small and tiny robots with human / animal characteristics.

As the trend continues, some researchers have analyzed the potential role of robots in supporting the elderly. Mast et al. conducted research using various kinds of questionnaire, which were designed for authors, to evaluate the usefulness of twenty-five (25) robotic services supported by description or photographs. Participants in the questionnaire were elders and caregivers from Italy, Germany and Spain. Older individuals rate emergency or critical care, stressful housekeeping and travel-related activities as best services. In contrast, social, collaborative and emotional services received lower marks. Differential results between the elderly and caregivers indicate that the views of both groups need to be taken into account in interpreting SAR. performance in adults[15].

Robotic applications for adults with mental retardation. We focus on robots used in patients with certain mental disorders (including AD patients). These types of robots focus on such things as social interaction in the form of touch, cognitive aid and physical and mental stimulation. In the case with Paro, a baby robot made in Japan. Its main objectives are to reduce stress for patients, to encourage their participation and to boost up their motivation[16]. Paro's robots have been tested with adults with dementia and outside many facilities. Many patients have shown reduction in their levels of stress and interactions not only with their caregivers but also between themselves.

In addition, the caregivers also feel reduction in their stress levels because patients require little attention while working with a robot. Another newly developed robot is named Babyloid, a baby robot is assembled to care for a patient with dementia. Its purpose is to reduce stress and increase the patient's motivation, giving us the important role of caring for the "child" but without the risk involving the real child. In this scenario, the whole idea is to make use "the doll therapy" because it has been researched and proven to enhance the mood of patients.

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# Figure 2 – Babyloid robot http://bit.ly/fMfa2C

On the other hand, there are other aid technologies that are intended to be used in the home. This is the approach introduced in the Com123 88 Int J project by Soc Robotic (2016) 8: 85-102 panionAble, which integrate a mobile robot with intelligent intelligence. In this research project the robot named Hector offers a variety of services such as agenda of the individual, video calls to socialise, and psychological training[17].

A smart home offers other tasks like tracking a user’s position at home or finding that a patient is falling down. The results were that not only did people with dementia receive benefits but also their caregivers (partners) which reduced some of their burden. There are also many studies with commercial robots that are not designed specifically for adult communication, but are used as areas of this policy. This is the story of a work presented by Kanamori et al. where they used the robot dog Aibo "animal treatment". They found that the stress and loneliness of the elderly had subsided after several home visits. The authors concluded that since Aibo was not designed for treatment, communication was not adequately encouraged and required further therapeutic interventions. However, Martín et al. use the Nao robot, a common purpose for humanoid trading, as a tool to promote understanding in the treatment of psychiatric patients. As a person with personality, Nao assists, for example, in physical therapy by performing movements that can be imitated directly by patients. In this case treatment sessions were controlled and developed by therapists. Describe the combination of music, movement, and robots. Their initial results showed that some of the patients' symptoms were significantly better compared to the results obtained using traditional methods. Many of these activities focus on a specific aspect of assistance: some of them focus on active involvement, which affects its structure and function. Some people put it first to accomplish certain tasks, such as reminders of daily activities or exercise, but their appearance is robust and unsympathetic. Most of them look after the needs of the patients in their construction, but not those of caregivers, who suffer from heavy load and do not have their time[18]. Broadbent conducted a study in which trained caregivers completed a questionnaire and were interviewed on the many functions performed by a robot in a retirement home. The results showed that citizens and workers obviously had different options. The RobAlz project differs from previous projects in two important ways: First, we follow the same path with Broadbent but rely on a different team of experts from the start of the project. Their understanding is crucial to the introduction of a real robot that will stay with AD patients in their homes or in nursing homes. Second, it aims to provide a variety of services and conditions of use to meet the needs of both patients and caregivers. The purpose is not to clarify the list of SAR hermetic functions, but to simplify the construction of various robots in the group. Therefore, robotic researchers who wish to create a robot that will help dementia patients and their caregivers, do not have to do it immediately: they are given other frameworks such as working conditions and common factors to consider in their designs[19].

1. **Parkinson’s disease**

Parkinson's disease is the most common neurodegenerative disease after Alzheimer's disease, with an estimated dose of 20/100 000 and an increase of 150/100 000. The cause of common clinical features is the death of dopaminergic neurons in the substantia nigra of midbrain. Lewy's body is present in part of the living neurons. At the pathological level there is an association with other neurodegenerative diseases including Alzheimer's disease, and this has been used to support the idea that these diseases may share certain common pathogenetic mechanisms[20].

1. Various studies have been performed on robotics in Parkinson's disease

Treadmill training (with or without the help of a robot) has been reported to improve balance skills in patients with Parkinson's disease (PD). However, its efficacy in post-test stability was tested mainly in patients with mild to moderate PD (Hoehn and Yahr class part3). Patients with serious illnesses can benefit from robotic-assisted training by the Gait-Trainer GT1, as the harness supports them with their feet placed at the feet of drivers. The aim of this study was to find that robotic-assisted training could have a positive effect on the postoperative posture of PD patients in Hoehn and Yahr section 3-4[21]

An active robotic walker assisted by the context of Parkinson's (PD) patients. Many PD patients not only lose balance but also have abnormal levels. These symptoms often cause PD patients to fall down easily and lead to a lower quality of life. they use the Hidden Markov Model (HMM) to analyze the tendency of PD patients, and then use our walker to help patients adjust their performance to normal while using hearing aids when abnormal habits are detected. To prevent the user from leaning forward before falling to the ground, the walker locks the engines when they are suddenly discovered by the user. In addition, the walker can record gait details from the user, making the therapists view the recovery process easier. Eventually, the road conditions in front of the passenger will be automatically updated, enabling the user to adjust his speed. To our knowledge, the proposed robotic walker should be the first program that can provide mobility for PD patients. In this study, the effectiveness and functioning of this program was evaluated by PD patients at two levels of adult care[22].

# The aim of this study was to evaluate the effectiveness of robotic-assisted training (RAGT), as well as the general exercise program (CEP), to improve the perception of PD, compared to standard gait training. Methods: Thirty-eight patients with low PD (H&Y 2-2.5) were randomly assigned to the study group (EG) or control group. Nineteen patients in EG received RAGT for 30 minutes (using the Lokomat device), while 19 controllers received standard training; both groups received 30 min of CEP. Participants were tested before (T0), immediately after (T1), and 12 weeks after the end of treatment (T2), using the 10-MWT, Tinetti Test and UPDRS-III vehicle. RAGT can significantly increase mobility, vehicle performance and up to three months. Therefore, their findings support the value of RAGT as a valid tool for PD23 renewal. An active robotic walker assisted by the context of Parkinson's disease (PD) patients. Most PD patients not only lose balance but also have abnormal measurements.

# Sensors 20 03399 g003 550

# Figure 3. Robot-assisted gait trainer. Lyra (Thera Trainer, Hochdorf, Germany) (left); Lokomat (Hocoma, Volketswil, Switzerland) (right). Schicketmueller, A.; Lamprecht, J.; Hofmann, M.; Sailer, M.; Rose, G. Gait Event Detection for Stroke Patients during Robot-Assisted Gait Training. *Sensors* 2020, *20*, 3399. https://doi.org/10.3390/s20123399

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1. **Amyotrophic lateral sclerosis**

ALS is considered to be a complex disease that involves many genetic and environmental factors that combine to transmit the disease to a person.1 excitotoxicity, inflammation, and apoptosis. In most patients, however, the exact cause is unknown[24].

The use of robotic tests usually occurs in people with ALS. People with ALS have sensorimotor impairment as expected, while others show severe mental retardation[25].

The positive effect of robotic rehabilitation on a patient outcome may be related to strenuous and repetitive aerobic9 exercise and work-based training with visual computer response. A visual response tool is used to increase vehicle mobility, involvement, and patient motivation during training. Therefore, it is reasonable to assume that robotic resuscitation will also work in patients with ALS, given that this may work in the brain and spinal cord plasticity (by increasing connectivity and reducing neural loss) and muscle strength and endurance (through measurable aerobic training).

Randomized clinical trials are needed to find out how robotic can reduce disease progression and improve quality of life in patients with ALS[26].

1. **CONCLUSION**

Robotics can assist in the precise diagnosis and monitoring of neurodegenerative diseases by providing quantitative and objective measurements of patients' motor skills, tremors, and other symptoms. This data helps clinicians track disease progression more accurately. Robotic devices can provide objective assessments of patients' motor function and cognitive abilities, reducing the potential for subjective bias in evaluations. This is particularly important for monitoring disease progression and assessing the effectiveness of treatments. Robotic devices can be used for therapeutic interventions such as physical therapy and rehabilitation. They offer controlled and repeatable movements, which can help patients regain or maintain motor skills and coordination. Robotics can adapt to individual patients' needs and abilities, providing tailored therapy sessions. This personalization can lead to more effective and efficient rehabilitation outcomes. For patients with mobility challenges, robotics can enable remote monitoring and telemedicine. Patients can perform therapeutic exercises under the guidance of healthcare professionals without needing to travel to a clinic. Robotic devices can facilitate motor learning and neuroplasticity by providing patients with repetitive and challenging exercises that encourage the brain to rewire itself. This can help patients learn new motor skills or compensate for lost functions. As neurodegenerative diseases often require long-term care, robotic devices can ease the burden on caregivers and healthcare facilities. Patients can perform exercises at home with guidance from robotic systems, reducing the need for frequent clinic visits. Interactive and gamified robotic exercises can make rehabilitation more engaging and enjoyable for patients, increasing their motivation to participate in therapy sessions. Robotic systems can collect longitudinal data on patients' progress over time. This information is valuable for understanding disease trajectories and optimizing treatment strategies. Robotic platforms provide researchers with standardized tools for studying neurodegenerative diseases and analyzing large datasets. This can lead to insights into disease mechanisms and the development of novel treatments. For conditions like Parkinson's disease that increase the risk of falls, robotics can offer balance training and assistive devices that help reduce the likelihood of accidents. In cases where neurosurgery is necessary, robotics can aid surgeons in performing delicate procedures with higher precision and reduced invasiveness. It's important to note that while robotics offers many benefits, its integration into the management of neurodegenerative diseases requires careful consideration of patient preferences, safety concerns, and individual disease characteristics. Collaboration between medical professionals, engineers, and researchers is crucial to developing and implementing effective robotic solutions that improve the quality of life for individuals with these conditions. Overall, medical AI has the potential to revolutionize healthcare by improving diagnostic accuracy, speeding up processes, reducing costs, and ultimately enhancing patient outcomes. However, its successful integration requires careful validation, ongoing monitoring, and collaboration between medical professionals and AI experts. Despite its potential benefits, medical AI also raises ethical and regulatory challenges. Ensuring patient privacy, maintaining the quality and accuracy of AI algorithms, and establishing clear guidelines for clinical decision-making are all important considerations. To conclude robotics is future mandate for rehabilitation as it is giving promising results in neurodegenerative diseases along with other manual therapies. More research is required to explore these diseases and play part in improving the quality of life of diseased individual.

**REFERENCES**

1. Fenwick, T.; Edwards, R. Exploring the impact of digital technologies on professional responsibilities and education. Eur. Educ. Res. J. 2015, 15, 117–131. [CrossRef]
2. Hilbert, M. Digital technology and social change: The digital transformation of society from a historical perspective. Dialogues Clin. Neurosci. 2020, 22, 189–194. [CrossRef]
3. Chassiakos, Y.R.; Radesky, J.; Christakis, D.; Moreno, M.A.; Cross, C. Children and adolescents and digital media. Pediatrics 2016, 138, e20162593. [CrossRef]
4. Small, G.W.; Lee, J.; Kaufman, A.; Jalil, J.; Siddarth, P.; Gaddipati, H.; Moody, T.D.; Bookheimer, S.Y. Brain health consequences of digital technology use. Dialogues Clin. Neurosci. 2020, 22, 179–187. [CrossRef]
5. Ghahramani, F.; Wang, J. Impact of smartphones on quality of life: A health information behavior perspective. Inf. Syst. Front. 2020, 22, 1275–1290. [CrossRef]
6. Cohen, J.; Bancilhon, J.M.; Grace, T. Digitally connected living and quality of life: An analysis of the Gauteng City-Region, South Africa. Electron. J. Inf. Syst. Dev. Ctries. 2018, 84, e12010. [CrossRef]
7. Georgieva, I.; Georgiev, G.V. Redesign me: Virtual reality experience of the line of life and its connection to a healthier self. Behav. Sci. 2019, 9, 111. [CrossRef] [PubMed]
8. Georgieva, I.; Georgiev, G.V. Reconstructing personal stories in virtual reality as a mechanism to recover the self. Int. J. Environ. Res. Public Health 2020, 17, 26. [CrossRef]
9. Lee, L.N.; Kim, M.J.; Hwang, W.J. Potential of augmented reality and virtual reality technologies to promote wellbeing in older adults. Appl. Sci. 2019, 9, 3556. [CrossRef]
10. Cortés-Pérez, I.; Nieto-Escamez, F.A.; Obrero-Gaitán, E. Immersive virtual reality in stroke patients as a new approach for reducing postural disabilities and falls risk: A case series. Brain Sci. 2020, 10, 296. [CrossRef]
11. Aulisio, M.C.; Han, D.Y.; Glueck, A.C. Virtual reality gaming as a neurorehabilitation tool for brain injuries in adults: A systematic review. Brain Inj. 2020, 34, 1322–1330. [CrossRef] [PubMed] Brain Sci. 2021, 11, 221 12 of 20
12. Hochberg, L.R.; Serruya, M.D.; Friehs, G.M.; Mukand, J.A.; Saleh, M.; Caplan, A.H.; Branner, A.; Chen, D.; Penn, R.D.; Donoghue, J.P. Neuronal ensemble control of prosthetic devices by a human with tetraplegia. Nature 2006, 442, 164–171. [CrossRef]
13. Onose, G.; Grozea, C.; Anghelescu, A.; Daia, C.; Sinescu, C.J.; Ciurea, A.V.; Spircu, T.; Mirea, A.; Andone, I.; Spânu, A.; et al. On the feasibility of using motor imagery EEG-based brain–computer interface in chronic tetraplegics for assistive robotic arm control: A clinical test and long-term post-trial follow-up. Spinal Cord 2012, 50, 599–608. [CrossRef]
14. Vansteensel, M.J.; Pels, E.G.M.; Bleichner, M.G.; Branco, M.P.; Denison, T.; Freudenburg, Z.V.; Gosselaar, P.; Leinders, S.; Ottens, T.H.; Van Den Boom, M.A.; et al. Fully implanted brain-computer interface in a locked-in patient with ALS. N. Engl. J. Med. 2016, 375, 2060–2066. [CrossRef]
15. Pandarinath, C.; Nuyujukian, P.; Blabe, C.H.; Sorice, B.L.; Saab, J.; Willett, F.R.; Hochberg, L.R.; Shenoy, K.V.; Henderson, J.M. High performance communication by people with paralysis using an intracortical brain-computer interface. eLife 2017, 6, e18554. [CrossRef]
16. Leeb, R.; Perez-Marcos, D. Brain-computer interfaces and virtual reality for neurorehabilitation. In Handbook of Clinical Neurology; Elsevier: Amsterdam, The Netherlands, 2020; Volume 168, pp. 183–197. [CrossRef]
17. Hwang, J.; Lee, S. The effect of virtual reality program on the cognitive function and balance of the people with mild cognitive impairment. J. Phys. Ther. Sci. 2017, 29, 1283–1286. [CrossRef]
18. Bauer, A.C.M.; Andringa, G. The potential of immersive virtual reality for cognitive training in elderly. Gerontology 2020, 66, 614–623. [CrossRef] [PubMed]
19. Gamito, P.; Oliveira, J.; Alves, C.; Santos, N.; Coelho, C.; Brito, R. Virtual reality-based cognitive stimulation to improve cognitive functioning in community elderly: A controlled study. Cyberpsychol. Behav. Soc. Netw. 2020, 23, 150–156. [CrossRef] [PubMed]
20. Liao, Y.Y.; Tseng, H.Y.; Lin, Y.J.; Wang, C.J.; Hsu, W.C. Using virtual reality-based training to improve cognitive function, instrumental activities of daily living and neural efficiency in older adults with mild cognitive impairment. Eur. J. Phys. Rehabil. Med. 2020, 56, 47–57. [CrossRef] [PubMed]
21. Miguel A. Salichs1 · Irene P. Encinar1 · Esther Salichs1 · Álvaro Castro-González1 · María Malfaz1, Study of Scenarios and Technical Requirements of a Social Assistive Robot for Alzheimer’s Disease Patients and Their Caregivers, Published online: 9 September 2015 © Springer Science+Business Media Dordrecht 2015
22. [AlessandroPicelliab](https://www.sciencedirect.com/science/article/abs/pii/S1353802012001903?via%3Dihub#!)[CamillaMelottia](https://www.sciencedirect.com/science/article/abs/pii/S1353802012001903?via%3Dihub" \l "!)[FrancescaOriganoa](https://www.sciencedirect.com/science/article/abs/pii/S1353802012001903?via%3Dihub" \l "!)[AndreasWaldnerc](https://www.sciencedirect.com/science/article/abs/pii/S1353802012001903?via%3Dihub" \l "!)[RaffaeleGimiglianod](https://www.sciencedirect.com/science/article/abs/pii/S1353802012001903?via%3Dihub" \l "!)[NicolaSmania](https://www.sciencedirect.com/science/article/abs/pii/S1353802012001903?via%3Dihub" \l "!), Does robotic gait training improve balance in Parkinson's disease? A randomized controlled trial, [Parkinsonism & Related Disorders](https://www.sciencedirect.com/science/journal/13538020), [Volume 18, Issue 8](https://www.sciencedirect.com/science/journal/13538020/18/8), September 2012, Pages 990-993
23. [Wei-Hao Mou](https://ieeexplore.ieee.org/author/37993825300); [Ming-Fang Chang](https://ieeexplore.ieee.org/author/38258503500); [Chien-Ke Liao](https://ieeexplore.ieee.org/author/38489171600); [Yuan-Han Hsu](https://ieeexplore.ieee.org/author/38540651500); [Shih-Huan Tseng](https://ieeexplore.ieee.org/author/37671929800); [Li-Chen Fu](https://ieeexplore.ieee.org/author/37278448600), Context-aware assisted interactive robotic walker for Parkinson's disease patients, [2012 IEEE/RSJ International Conference on Intelligent Robots and Systems](https://ieeexplore.ieee.org/xpl/conhome/6363628/proceeding)
24. [Anna Furnari](https://www.tandfonline.com/author/Furnari%2C+Anna), [Rocco Salvatore Calabrò](https://www.tandfonline.com/author/Calabr%C3%B2%2C+Rocco+Salvatore), [Maria Cristina De Cola](https://www.tandfonline.com/author/de+Cola%2C+Maria+Cristina), [Michelangelo Bartolo](https://www.tandfonline.com/author/Bartolo%2C+Michelangelo), [Alberto Castelli](https://www.tandfonline.com/author/Castelli%2C+Alberto), [Alessia Mapelli](https://www.tandfonline.com/author/Mapelli%2C+Alessia) Robotic-assisted gait training in Parkinson's disease: a three-month follow-up randomized clinical trial,  [International Journal of Neuroscience](https://www.tandfonline.com/toc/ines20/current),Volume 127, 2017 - [Issue 11](https://www.tandfonline.com/toc/ines20/127/11)
25. Gordon PH. Amyotrophic lateral sclerosis: pathophysiology, diagnosis and management. *CNS Drugs.*2011;25:1–15. [[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/21128691)]
26. [Leif Simmatis](https://www.tandfonline.com/author/Simmatis%2C+Leif), [Ghada Atallah](https://www.tandfonline.com/author/Atallah%2C+Ghada), [Stephen H. Scott](https://www.tandfonline.com/author/Scott%2C+Stephen+H), [Sean Taylor](https://www.tandfonline.com/author/Taylor%2C+Sean),The feasibility of using robotic technology to quantify sensory, motor, and cognitive impairments associated with ALS  [Amyotrophic Lateral Sclerosis and Frontotemporal Degeneration](https://www.tandfonline.com/toc/iafd20/current),Volume 20, 2019 - [Issue 1-2](https://www.tandfonline.com/toc/iafd20/20/1-2)