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Use of multimedia therapeutic tools in the post-stroke rehabilitation process

review paper
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ABSTRACT
Stroke remains one of the leading causes of disability and death worldwide, resulting in significant social and economic costs. Effective post-stroke rehabilitation, including physiotherapy, occupational therapy, speech therapy and psychological support, is crucial for improving motor and cognitive functions and quality of life in patients. In recent decades, there has been dynamic development of multimedia therapeutic tools, such as virtual reality (VR), robotics, mobile applications and telemedicine. These technologies allow for the personalisation of exercises, greater patient engagement and monitoring of therapy progress. The introduction of VR systems, computer games and motion controllers has revolutionised motor and cognitive rehabilitation, and the use of gamification elements increases motivation and the number of repetitions of exercises performed. A review of studies confirms the effectiveness of VR and other multimedia tools in improving upper limb function, gait, balance and cognitive function and reducing the symptoms of depression after a stroke, as well as strengthening motivation for rehabilitation. Modern technologies also facilitate performing exercises at home, which is particularly important for maintaining long-term therapeutic activity. Multimedia tools are a valuable complement to traditional methods, contributing to the intensity, effectiveness and attractiveness of the post-stroke rehabilitation process.
Key words: stroke, rehabilitation, virtual reality

Introduction

Stroke is a serious threat to public health worldwide, affecting an average of 15 million people each year [1, 2] and is the third most common cause of disability, with approximately 50% of stroke survivors being chronically disabled [3]. In Europe, it is the leading cause of disability in adults, and forecasts for 2017–2047 predict an increase in the incidence of stroke, even though mortality from this disease is expected to decrease by 17% [4]. Worldwide, stroke is the second most common cause of death, accounting for 11.8% of all deaths, and the third most common cause of disability, with 4.5% of all cases of disability worldwide caused by stroke. In 2019, there were nearly 101 million stroke survivors worldwide, with 12.2 million new cases [5]. Stroke also accounts for a significant health and economic burden, especially in countries such as China and the United States. In the United States, stroke is the fifth leading cause of death, and the annual costs associated with its treatment and patient care are estimated at $46 billion [6]. With more than 9% of the world's population aged 65 and over, the costs of the disease are high, and research on stroke will aid in healthcare decision-making [7] and help healthcare systems cope with, prevent and minimise the burdensome demand . Therefore, there is an urgent need to understand the risk factors and to effectively prevent and treat stroke. New strategies for the treatment, prevention and management of acute stroke that have emerged in recent years have dramatically improved patient outcomes [8]. Despite all these advances, stroke remains a leading cause of long-term disability and cognitive deficits worldwide. Therefore, understanding and combating stroke requires global efforts to improve healthcare systems and raise public awareness of this disease.

The current level of development of post-stroke rehabilitation makes it possible to use ever newer technologies in the therapy process. The present work aims to determine whether the combination of physical therapy with multimedia elements brings greater benefits

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to patients compared to conventional methods of neurorehabilitation.

Definition and classification of strokes – types of strokes and their symptoms

Strokes can be divided into two main types: ischaemic stroke and haemorrhagic stroke, each of which is characterised by different mechanisms of formation and clinical symptoms [9, 10]. Ischemic stroke occurs as a result of blocked blood flow through a blood vessel, leading to hypoxia and necrosis of brain tissue [11]. Ischemia triggers a cascade of events that begins with the loss of electrical energy of the cell membrane function and progresses to membrane dysfunction under the influence of calcium influx, leading to calcium-dependent excitotoxicity, the production of reactive oxygen species, and ultimately cell membrane destruction and cell lysis [12]. Embolism is the most common mechanism of stroke. The vast majority of embolisms are blood clots from the heart (cardioembolic disease) caused by heart disease. Common heart disorders leading to stroke include atrial fibrillation, heart valve defects, and cardiomyopathy caused by myocardial infarction or hypertension. Another common cause of ischaemic stroke is arterial embolism associated with atherosclerosis or arterial dissection [12, 13]. Symptoms of ischaemic stroke include: sudden weakness or paralysis on one side of the body, usually involving the face, arm and leg; problems with speaking or understanding speech (aphasia); visual disturbances, such as a loss of vision in one eye or in the field of vision; sudden difficulty walking, dizziness, loss of balance or coordination; and headache, although less typical of ischaemic stroke than of haemorrhagic stroke [14].

A haemorrhagic stroke occurs when a blood vessel ruptures, causing bleeding into the brain. It can be divided into intracerebral haemorrhage, when bleeding occurs directly in the brain tissue, and subarachnoid haemorrhage, when blood accumulates in the subarachnoid space [15]. Symptoms of a haemorrhagic stroke may include: sudden, very severe headache, often described as ‘the worst pain of your life’; sudden weakness or paralysis on one side of the body; problems with speaking or understanding speech; visual disturbances; loss of balance and coordination; and loss of consciousness, confusion or drowsiness [16].

The first recorded use of the word ‘stroke’ as a lay term was in 1599, attributing the sudden onset of symptoms to a ‘blow from the hand of God’ [17]. In the past, both types of stroke were often referred to as ‘apoplexy’, which meant sudden brain dysfunction with preserved pulse and breathing. It is now known that apoplexy included various conditions that mimicked stroke, such as migraine and epilepsy [18]. Historical studies, such as those conducted by Johann Jakob Wepfer, who was the first to describe the relationship between stroke and cerebral haemorrhage, and Giovanni Morgagni, who distinguished between bloody and serous causes of stroke, were crucial in understanding the mechanisms of this disease. Further medical advances have allowed for more accurate diagnosis and differentiation between ischaemic and haemorrhagic strokes, which is important for effective treatment and improved patient prognosis [19, 20].

Importance of post-stroke rehabilitation

Stroke rehabilitation plays a key role in the recovery process and improvement of quality of life for patients who have experienced this serious neurological incident. A stroke can lead to a variety of neurological deficits, including motor, speech and vision disorders, as well as changes in cognitive functions. Without proper rehabilitation, these limitations can persist for a long time, significantly reducing the patient’s level of independence [21, 22]. The goal of stroke rehabilitation is to maximise the restoration of lost functions, reduce the effects of disability, and support patients in adapting to their new living conditions [22]. This process begins in the acute phase, often in hospital, and continues on an outpatient basis or in specialised rehabilitation centres [23]. Rehabilitation includes a wide range of therapies, including physiotherapy, occupational therapy, speech therapy and psychological support. Physiotherapy focuses on improving muscle strength, motor coordination and the ability to move independently [24]. Occupational therapy helps patients learn or reacquire the skills necessary for daily functioning, such as dressing, eating and personal hygiene [25]. Speech therapy plays a key role in regaining communication skills, both in speech and language comprehension. Patients can work on improving articulation, fluency, and understanding and expressing thoughts [26]. Psychological support, on the other hand, helps to cope with the emotional and social effects of stroke, such as depression, anxiety, or changes in interpersonal relationships [27]. Systematic and intensive rehabilitation can significantly reduce the risk of long-term disability and improve the chances of returning to an independent life. This process is long term and requires the commitment of both the patient and the therapeutic team. An individually tailored rehabilitation programme that takes into account the specific needs of the patient is key to achieving optimal results.

Rehabilitation after a stroke

Stroke rehabilitation is a multi-stage process aimed at gradually restoring the patient to the highest possible level of functioning. Each phase of rehabilitation plays an important role in the recovery process [28]. The first phase, known as the acute phase, lasts for the first few days or weeks after the stroke. Its main goal is to stabilise the patient's health and prevent complications associated with immobility, such as bedsores, deep vein thrombosis or pneumonia. In this phase, early mobilisation and breathing exercises play a key role. It is also important to make an initial diagnosis of neurological deficits and to rehabilitate them. Rehabilitation in this phase is usually carried out in hospital and includes initial physical exercises and psychological support for the patient and their family, who often experience difficult moments after a stroke [29]. The next phase, called early rehabilitation, lasts from several weeks to several months after the stroke. It focuses on restoring basic motor functions such as walking, sitting and standing up, as well as learning independence in daily activities such as dressing, eating and personal hygiene. Rehabilitation in this phase is more intensive and includes a variety of therapies such as physiotherapy, occupational therapy, speech therapy and neuropsychological therapy. The patient may be rehabilitated in a hospital, a specialised rehabilitation centre, and sometimes at home [30]. The third phase, late rehabilitation, lasts from several months to even several years after the stroke. Its main goal is to further strengthen motor and cognitive functions and improve balance and coordination to prevent falls. In this phase, the patient perfects the skills needed to function independently and may use more advanced forms of therapy, such as robotics or virtual reality. As mentioned above, this process can take many months or even years, depending on the extent of the brain damage and the patient's individual progress. It is also a time when the patient learns to live with the long-term consequences of stroke and adapts to their new reality [31]. The final phase, the maintenance phase, lasts throughout the patient's life. Its aim is to maintain the results achieved in rehabilitation, and to prevent the recurrence of stroke and complications related to disability. Rehabilitation in this phase may include regular check-ups with specialists, exercises performed at home and participation in support groups for stroke survivors. The goal is to maintain the best possible physical and mental condition and further social integration [32]. Each of these phases is crucial for a full recovery, and their effectiveness depends on the individual needs of the patient and the commitment of both the patient and the therapeutic team.

Rehabilitation goals and methods

The main physiotherapy goals in post-stroke rehabilitation focus on restoring maximum mobility and improving quality of life. The first and most important goal is to achieve basic motor functions, such as the ability to walk, maintain balance, and perform everyday activities [33]. To this end, the physiotherapist works to strengthen weakened muscles, improve coordination, and increase the range of motion in the joints. Another goal of physiotherapy is to prevent complications resulting from prolonged immobilisation, such as muscle contractures, bedsores, and blood clots. Regular exercise and patient mobilisation are key to maintaining proper blood circulation and muscle and joint flexibility [34].

A variety of physiotherapy methods are used in the post-stroke rehabilitation process, which are tailored to the individual needs of the patient. One of the most commonly used methods is kinesitherapy, or movement therapy. It includes exercises aimed at strengthening muscles and improving motor coordination and balance. Patients also learn weight-bearing techniques that help stabilise them while walking and performing other motor activities [35, 36]. Another important method is physical therapy, which uses various forms of physical energy, such as electricity, ultrasound or light, to reduce pain, improve circulation and accelerate tissue healing. Massages and joint mobilisation are also commonly used to relax tense muscles and increase joint flexibility [37]. In recent years, modern technologies such as robotics and virtual reality have played an increasingly important role in post-stroke physiotherapy. Robotics allows for precise movement exercises, which is particularly helpful for patients with severe motor deficits. Virtual reality enables the simulation of various movement scenarios, which motivates patients to actively participate in therapy and helps them quickly regain their motor skills [38]. Physiotherapy rehabilitation after a stroke requires systematic work and patience, both on the part of the patient and the therapeutic team. With appropriately selected methods and clearly defined goals, it is possible to significantly increase the patient's independence and improve their quality of life.

Multimedia therapeutic tools

The development of multimedia therapeutic tools in stroke rehabilitation has progressed rapidly over the last few decades, with its origins dating back to technological advances and growing interest in neurorehabilitation. As early as the 1980s and 1990s, computers began to be used in therapy, albeit on a limited scale. The first computer programmes supporting brain neuroplasticity were developed at that time, which were mainly used to improve patients' cognitive and communication functions. However, their capabilities in the field of motor rehabilitation were limited [39]. At the beginning of the 21st century, the development of technologies such as computer games, virtual reality (VR) and interactive sensory systems opened up new possibilities in stroke rehabilitation. Systems were developed that enabled patients to perform physical exercises in a virtual environment, which made it possible to engage more senses and better adapt the therapy to the individual needs of the patient [40]. Between 2000 and 2010, the concept of entertainment-therapeutic games developed, which, in addition to the entertainment element, were designed to support therapy. The introduction of motion controllers, such as the Nintendo Wii and Microsoft Kinect, revolutionised physical rehabilitation, allowing patients to perform motor exercises in an attractive form while tracking their progress [41]. Between 2010 and 2020, there was rapid development in VR and augmented reality (AR) technologies, which began to be used in motor and cognitive training. These innovations allowed patients to simulate real-life motor tasks, which promoted neuroplasticity and accelerated the rehabilitation process [42]. At the same time, rehabilitation robots were developed, which, in combination with multimedia tools, supported the therapy of stroke patients, enabling strength and coordination exercises [40]. Since 2015, stroke rehabilitation has increasingly used artificial intelligence (AI) and machine learning tools to support the personalisation of therapy and monitor patient progress [43]. Telemedicine and remote multimedia tools have become crucial, enabling patients to continue therapy at home, which proved particularly important during the COVID-19 pandemic [44]. Platforms using advanced data analysis and biofeedback to monitor rehabilitation progress in real time have also emerged [45]. Recent studies indicate that multisensory technology can significantly improve cognitive function in stroke patients, offering new therapeutic possibilities and increasing patient engagement in the rehabilitation process [46]. Multimedia therapeutic tools have significantly accelerated rehabilitation processes, providing patients with more engaging, precisely tailored and effective forms of therapy.

Definition and types of multimedia therapeutic tools

Multimedia therapeutic tools in the context of stroke patient rehabilitation are a variety of technologies and materials that combine different forms of stimuli (e.g., sound, image, video, interaction) to support the rehabilitation process. These tools may include mobile applications, computer programmes, virtual reality, as well as educational materials that engage patients in physical and cognitive exercises. Their aim is not only to improve motor and cognitive functions but also to increase patient motivation and engagement in the rehabilitation process. Thanks to multimedia elements, therapy can be tailored to the individual needs of patients, which promotes more effective achievement of therapeutic goals [47–49]. Virtual reality (VR) has become a modern tool used in rehabilitation, combining elements of biomechanics, internet technology engineering, cognitive neurobiology and physiotherapy. In particular, VR shows promising application in post-stroke rehabilitation, allowing patients to use computer-generated programmes that simulate real objects and activities, which may be more effective than traditional methods of exercise therapy [50]. Virtual reality creates opportunities to personalise exercises and tailor them to patients' needs, which further increases the level of engagement and effectiveness of therapy. The use of VR engages patients by introducing elements of 'gamification', which increases the number of repetitions performed and their motivation. Patients, observing their progress, are also encouraged to increase the difficulty level of the exercises, which has a positive effect on the effectiveness of rehabilitation. The VR system allows patients to interact with the virtual environment, in particular by influencing visual and proprioceptive feedback mechanisms, which further supports therapeutic processes and the development of neuroplasticity [51]. VR therapy involves generating computer simulations that provide sensory-motor interaction, which is particularly beneficial for post-stroke patients, who often have limited opportunities for interaction in everyday life [52]. Another advantage of VR is the ability to use simulations of everyday situations that may be unattainable for patients due to their cognitive, motor and mental limitations. This approach makes therapy more engaging and patients more motivated to perform exercises, which is particularly important in long-term rehabilitation programmes [6]. Thanks to various interfaces, VR enables the creation of individualised exercise programmes, which further supports the therapy process [53].

Use of multimedia therapeutic tools in post-stroke rehabilitation – what benefits can they bring?

Studies using multimedia therapeutic tools were reviewed. The therapeutic tools reviewed focused on everyday tasks (challenges). Tools that focused on a single movement were excluded.

Table 1 presents studies using multimedia therapeutic tools.

Motor and functional therapy

A study by Ase et al. [54] showed that four weeks of home-based upper limb rehabilitation using VR (RAPAEL Smart Glove™) significantly improves motor function in patients after chronic stroke. The VR group showed a greater increase in Fugl-Meyer score (mean +8.9 vs +1.7; p = 0.027), higher hand use frequency in MAL-14 AoU (+0.67 vs +0.11; p = 0.014), better JTT scores (p = 0.002) and an increase in the number of blocks transferred in the BBT test (+5.6 vs 0; p = 0.002) compared to the control group. The results indicate a higher effectiveness of task-based VR therapy in improving upper limb function in stroke survivors. In a study by Jo et al. [55], the use of immersive mirror therapy in 360° VR (360MT) technology resulted in a statistically significant functional benefits in upper limb rehabilitation after stroke. On the Fugl-Meyer scale (FMA-UE), patients in the 360MT group achieved an average increase from 34.67 ± 10.96 to 37.26 ± 11.22 points, while in the traditional mirror therapy (TMT) group, the increase was from 36.93 ± 10.46 to 38.40 ± 10.64, and in the control group (CG) from 38.06 ± 11.94 to 38.80 ± 12.13. The differences

Table 1. Studies using multimedia therapeutic tools

Year	Author	Number of patients	Part of the body/function undergoing rehabilitation	Duration of the intervention	Control group	Group studied	Measuring tools	Main results (experimental group vs control group)
2025	Ase et al. [54]	14	upper limb	4 weeks (30 min a day, 5 days a week)	a set of conventional upper limb exercises	Ratael Smart Glove™; Neofect Co., Yung-in, Korea	Fugl-Meyer Assessment (FMA-UE), Jebsen-Taylor Hand Function Test (JTHFT), Box and Blocks Test (BBT)	Fugl-Meyer score (average +8.9 vs +1.7, p = 0.027), Better JTT scores (p = 0.002), BBT test (+5.6 vs 0, p = 0.002)
2024	Jo et al. [55]	45	upper limb	control intervention: 60 min per day 5 days per week for 4 weeks (all three groups) intervention study: 30 min per day 3 days per week for 4 weeks (study groups only)	a set of conventional upper limb exercises	1. Classic mirror therapy for the upper limb (test group no. 1) 2. Insta 360° X3, Insta 360, China (test group no. 2)	Fugl-Meyer Assessment (FMA-UE), manual function test (MFT), box & block test (BBT)	Fugl-Meyer score (average increase from 34.67 ± 10.96 to 37.26 ± 11.22 points vs from 38.06 ± 11.94 to 38.80 ± 12.13), Manual Function Test (average from 14.13 ± 3.94 to 16.06 ± 4.51 vs from 15.60 ± 4.76 to 15.86 ± 5.08), Box and Block Test (average from 1.33 ± 1.34 to 2.66 ± 1.75 vs from 1.40 ± 1.35 to 1.60 ± 1.63)
2023	Sana et al. [56]	34	balance and gait abilities	8 weeks 3 times a week	Vestibular Rehabilitation Therapy (VRT)	Wii Fit Plus	Timed Up and Go (TUG), Dizziness Handicap Inventory (DHI), Dynamic Gait Index (DGI)	Dynamic Gait Index (VR 13.3 ± 2.28 → 19.2 ± 2.11 vs VRT 11.26 ± 2.86 → 15.66 ± 2.69; p = 0.001)

2021	Kayabinar et al. [57]	30	gait, balance, functioning in dual tasks	6 weeks twice a week	robot-assisted gait training (RAGT)	VR-augmented RAGT (RoboGait VR)	10-Metre Walk Test (10MWT), dual-task performance, the Functional Gait Assessment (FGA), The Rivermead Mobility Index (RMI), Berg Balance Scale (BBS), The Fall Efficacy Scale International (FES-I), Functional Independence Measure (FIM)	study group: 10MWT 30.77 → 26.43 s (p = 0.009), dual motor-motor task 32.28 → 29.02 s (p = 0.006), dual motor-cognitive task 31.96 → 29.58 s (p = 0.005), dual cognitive task performance 6.63 → 3.15 s (p = 0.036); FGA 12.60 → 15.46, RMI 12.26 → 13.13, BBS 44.93 → 47.73, FIM 106.13 → 108.86 control group: insignificant changes in 10MWT and dual-task, FGA 13.60 → 16.40, RMI 11.73 → 12.86, BBS 44.26 → 47.46, FIM 109.53 → 111.93
2020	Faria et al. [58]	36	cognitive functions (cognitive-motor)	4 weeks 3 times a week	traditional neuropsycho-logical therapy	Reh@City v2.0	Montreal Cognitive Assessment (MoCA), assessment of executive functions	MoCA (average 23 → 25 vs 21 → 21)
2019	Rogers et al. [59]	21	cognitive functions	4 weeks 5 times a week	classic physiotherapy	Elements Virtual Rehabilitation (VR)	MoCA	MoCA (average 18.4 → 24.8 vs 19.2 → 21.4)
2014	Friedman et al. [60]	12	upper limb	a total of 4 weeks of intervention	conventional therapy and isometric grip training	MusicGloves	Intrinsic Motivation Inventory (IMI), Box and Blocks Test	IMI – patients indicated the MusicGloves method as the most motivating for further work
2021	Winter et al. [61]	50	gait	6 weeks 5 times a week	treadmill without VR	treadmill with monitor, treadmill and head-mounted display (HMD)	Intrinsic Motivation Inventory (IMI)	IMI – patients decided that therapies combined with VR systems were definitely more motivating for further work.
2022	Kiper et al. [51]	60	comprehensive rehabilitation, symptoms of depression	6 weeks 20 min a day 5 times a week	Schultz autogenic training + standard neurological rehabilitation	VR TierOne (therapeutic garden) + standard neurological rehabilitation	Geriatric Depression Scale (GDS-30), Hospital Anxiety and Depression Scale (HADS), AIS, GSES, VAS, Barthel Index, IADL, RMA	GDS (average from 13.77 to 7.43 vs from 13.40 to 10.23) HADS (average from 14.15 to 10.40 vs from 15.11 to 12.21)

between the groups were statistically significant ($p < 0.001$), with 360MT outperforming TMT and CG in the post hoc analysis. In the Manual Function Test (MFT), an improvement was noted from 14.13 ± 3.94 to 16.06 ± 4.51 in the 360MT group, compared to 13.53 ± 3.09 to 14.60 ± 3.15 in the TMT group and 15.60 ± 4.76 to 15.86 ± 5.08 in the CG ($p < 0.001$). In the Box and Block Test (BBT), the number of blocks moved in the 360 MT group increased from 1.33 ± 1.34 to 2.66 ± 1.75, in the TMT group from 1.20 ± 1.47 to 1.80 ± 1.61, while in the control group, the change was marginal – from 1.40 ± 1.35 to 1.60 ± 1.63 ($p < 0.001$). The results clearly indicate that immersive VR technology significantly improves motor performance, functionality and manipulative abilities of the upper limb in post-stroke patients compared to classical therapy and standard physiotherapy.

Gait and balance therapy

The study by Sana et al. [56] assessed the impact of vestibular rehabilitation (VRT) and virtual reality (VR) therapy on balance, dizziness and gait in patients in the subacute phase after a stroke. Both interventions resulted in significant improvement, but their effectiveness varied depending on the parameter assessed. The VR group showed significantly greater improvement in balance and gait – the TUG (Timed Up and Go) and DGI (Dynamic Gait Index) scores improved significantly both within the group ($p < 0.001$) and between groups (DGI: VR 13.3 ± 2.28 → 19.2 ± 2.11 vs VRT 11.26 ± 2.86 → 15.66 ± 2.69; $p = 0.001$). In contrast, the VRT group showed a significantly greater reduction in dizziness as assessed by the Dizziness Handicap Inventory (DHI) – the median decreased from 54 to 22 points ($p = 0.001$), compared to VR (42 → 32 points; $p = 0.001$), with a significant advantage of VRT between the groups ($p < 0.01$). In summary, VR therapy was more effective in improving balance and gait, while VRT was more effective in reducing dizziness in patients after subacute stroke.

A study by Kayabinar et al. [57] showed that the use of virtual reality integrated with robotic gait training (VR-RAGT) in patients with chronic stroke contributed to a significant improvement in walking speed and performance in complex tasks (dual-task). The experimental group showed a statistically significant increase in speed in the 10MWT test ($p = 0.009$), both in single and dual tasks (motor-motor and motor-cognitive; $p < 0.01$). Gait function (FGA), mobility (RMI), balance (BBS) and functional independence (FIM) also improved, with statistically significant improvement within the group ($p < 0.05$), although there were no intergroup differences. RAGT therapy without VR also led to improvement in these areas. The results of the presented research support the fact that the inclusion of multimedia elements in the process of gait and balance training can result in a faster return to functional fitness.

Cognitive therapy

The study by Faria et al. [58] assessed the impact of cognitive-motor training using virtual reality (VR) on cognitive functions in people after ischemic stroke. The intervention lasted 12 sessions, during which patients performed tasks requiring simultaneous involvement of motor and cognitive functions, such as attention, working memory, spatial orientation or planning. In the group undergoing VR therapy, a significant improvement in executive functions and global cognitive functions assessed using the Montreal Cognitive Assessment (MoCA) was observed ($p < 0.001$). This improvement was significantly greater than in the control group undergoing classical therapy, which was confirmed by an intergroup analysis ($p = 0.002$). In addition, patients reported higher levels of motivation and commitment, which may be crucial in long-term cognitive neurorehabilitation. In conclusion, the study confirms that VR can be an effective tool for post-stroke cognitive therapy, enabling the integration of motor and executive functions in an environment with a high level of immersion and adaptability.

The study by Rogers et al. [59] evaluated the impact of virtual reality (VR) therapy on cognitive functions in patients after ischemic stroke. After 4 weeks of therapy (5 days a week), the VR group achieved significantly greater improvement in cognitive function (MoCA 18.4 → 24.8; +6.4 points; $p < 0.001$), motor (BBT-MAH 21.8 → 39.1; $p < 0.001$) and functional (NFI, all subscales) functions than the control group (MoCA 19.2 → 21.4; +2.2 points; $p = 0.004$). The proportional increase in MoCA was almost three times higher in the VR group (57.2% vs 20.7%; $p < 0.001$). The effects persisted in the assessment after one month. Rehabilitating featuring a VR component proved to be more effective than standard rehabilitation alone in improving cognitive, motor and daily functioning. Multimedia therapy tools make it possible to provide the patient with therapy that is not limited to strenuous repetition of movement patterns. Therapy using multimedia provides tasks that the patient may encounter every day.

Motivation for rehabilitation

Friedman et al. study [60] highlights the significant impact of MusicGlove therapy on patients' motivation for rehabilitation. This system is based on the mechanics of a rhythmic game, in which the user performs finger movements in tune with musical visual cues, which creates an immersive and dynamic environment. This type of interactivity is significantly different from the monotonous exercises used in traditional hand therapy. The participants of the study rated MusicGlove therapy as much more satisfying and pleasant compared to conventional therapy, which was confirmed by the results of the Internal Motivation Inventory (IMI) – these differences were statistically significant ($p < 0.05$). The higher level of motivation was not only subjective but also translated into greater involvement in performing exercises and better functional results. Moreover, patients were more likely and willing to perform sessions with MusicGlove, which increased the intensity of training without the need for external pressure from the therapist. The authors indicate that mechanisms of gamification and immediate feedback may play a key role in maintaining long-term rehabilitation activity.

In the study by Winter et al. [61], the use of immersive virtual reality (VR with HMD goggles) during gait rehabilitation induced the highest level of motivation in participants – both stroke and MS patients, as well as healthy people. Based on the Intrinsic Motivation Inventory (IMI) questionnaire, it was shown that the condition with VR goggles was significantly more motivating than VR on a monitor and a traditional treadmill.

Post-stroke depression

The study by Kiper et al. [51] evaluated the effect of immersive virtual reality therapy on symptoms of depression in patients after ischemic stroke. The use of VR brought a significant reduction in the severity of depression as measured by the Geriatric Depression Scale (GDS-30). The average GDS-30 score decreased from 13.77 before the intervention to 7.43 after therapy, and this effect was also maintained after three weeks of observation (7.17). The percentage of people with a score below the threshold of depression (GDS-30 < 10) increased in this group from 0% before therapy to 67% after the intervention and 73% in long-term observation. The differences from the control group were statistically significant ($p < 0.0001$), which confirms that immersion VR therapy can be an effective support in reducing depressive symptoms in stroke patients.

Restrictions

Functional and/or cognitive impairments may hinder the independent use of multimedia tools, limiting the precision of movements required to operate devices or perform exercises in a virtual environment. In addition, visual impairments or aphasia may further hinder understanding of commands and proper interaction with therapeutic programmes. As a result, functional deficits after a stroke can significantly limit the ability to fully utilise the potential of multimedia therapy. It should also be mentioned that not all multimedia therapeutic tools will be suitable for severely limited patients. In the study by Asa et al. [54], patients had to have minimal strength and/or functional ability in their upper limbs to benefit from the therapy.

Conclusions

The introduction of multimedia therapeutic tools to the post-stroke rehabilitation process is a significant step towards increasing the effectiveness and individualisation of therapy. Modern technologies, such as virtual reality systems, robotics, mobile applications and telemedicine platforms, enable better adjustment of exercises to the patient's needs, increase their engagement and motivation, and allow for systematic assessment of treatment progress. The availability of these solutions, including during treatment at home, favours the continuation of therapy after the end of hospital treatment and can contribute to improving the quality of life of people after stroke. In light of the available research, the implementation of multimedia tools in post-stroke rehabilitation should be treated as a valuable supplement to traditional methods, which in many cases leads to faster and more lasting improvement in the functioning of patients.

Multimedia therapeutic tools should be incorporated into post-stroke rehabilitation at a stage when the patient is able to actively participate in therapy and understand instructions, most often during the subacute period. At this time, the brain has the greatest neuroplastic potential, which promotes effective learning of new skills and reorganisation of functions. The use of multimedia can further stimulate neuroplastic processes by providing multisensory stimuli, increasing patient engagement and the effectiveness of rehabilitation.

Ethical approval

The conducted research is not related to either human or animal use.

Conflict of interest

The author states no conflict of interest.

Disclosure statement

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