GAME-BASED HAND REHABILITATION TO IMPROVE MOBILITY FOR POST-STROKE PATIENTS

A PROJECT REPORT

submitted by

ATHUL V

TKM21MECI07

to

the APJ Abdul Kalam Technological University

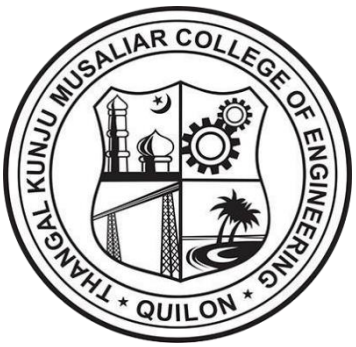
in partial fulfillment of the requirements for the award of the Degree

of

Master of Technology

In

Computer Integrated Manufacturing.



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DECLARATION

I, Athul v, hereby declare that the project report "Game-Based hand rehabilitation to improve mobility for post-stroke Patients." submitted for partial fulfillment of the requirements for the award of the degree of Master of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by me under supervision of Subhash N N, Scientist/Engineer Department of Medical Device Engineering SCTIMST Govt of India, Kannan S, Assistant Professor, Department of Mechanical Engineering, TKM College of Engineering, Kollam. This submission represents my ideas in my own wordsand where ideas or words of others have been included, I have adequately and accurately cited and referenced the original sources. I also declare that I have adhered to the ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or sourcein my submission. I understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained.This report has not been previously formed the basis for the award of any degree, diploma, or similar title of any other University.

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CERTIFICATE

This is to certify that the report entitled **'GAME-BASED HAND REHABILITATION TO IMPROVE MOBILITY FOR POST-STROKE PATIENTS'** submitted by **'ATHUL V.' '(TKM21MECI07)'** to the APJ AbdulKalam Technological University in partial fulfillment of the requirements for the award of the Degree of Master of Technology in Computer Integrated Manufacturing, Mechanical Engineering is a bonafide record of the project work carried out by him under my guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

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Place: KOLLAM **ATHUL V**

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ABSTRACT

Stroke is a significant global health concern affecting millions of people each year. Stroke-related disabilities can manifest in a variety of ways, and their impact on a person's life can be very different. Strokes can cause problems like Physical disabilities, communication difficulties, etc. Eighty percent of stroke survivors are constrained by upper limb impairment, and only five to ten percent demonstrate full functional recovery. The process of recovery and the likelihood of improvement differ as well. In order to recover function and accommodate their disabilities, stroke survivors need the assistance of rehabilitation and therapy. Significant rehabilitation methods with a simple application are required to increase patient compliance and exploit the potential neuroplasticity that could improve an improvement in quality of life. Gamification research trends have shown great variation in many e-health domains, particularly when it comes to addressing the concerns of rehabilitation and physical activity. Therefore, the purpose of the study is to check the feasibility of introducing gamification in the field of stroke rehabilitation. This study includes the responses of different clinicians and physiotherapists, game development using a recommended game engine for hand rehabilitation and the required hardware for development, and data collection

Keywords: Stroke, Rehabilitation, neuroplasticity, gamification, game development

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ABBREVIATIONS

DALY- Disability Adjusted Life Years

ADLs - Activities in Daily Living

VR – Virtual Reality

AR – Augmented Reality

FES- Functional Electrical Stimulation

CP- Cerebral Palsy

CIMT- Constraint-Induced Movement Therapy

PROM- Passive Range of Motion

AROM- Active Range of Motion

MCP- Metacarpophalangeal

PIP- Proximal Interphalangeal

DIP- Distal Interphalangeal

EDC- Extensor digitorum Cmmunis

EIP- Extensor Indicis Porprius

IDE- Integrated Development Environment

MRCs- Medical Research Council Scale

CHAPTER 1

INTRODUCTION

Stroke is a significant global health concern affecting millions of people each year. it is a serious medical condition that occurs when the blood supply to the brain is interrupted or reduced, leading to the death of brain cells. It requires rapid medical attention and is frequently referred to as a "brain attack". Prompt recognition of stroke symptoms and quick medical intervention are crucial for minimizing the damage and improving the chances of recovery.

The brain is a sophisticated organ that regulates several physical processes, including speech, memory, emotion, and movement. The particular part of the brain affected by a stroke dictates the symptoms that a person may experience. One-sided weakness or paralysis, trouble speaking or understanding speech, vision issues, dizziness, excruciating headaches, and loss of coordination are all common signs of a stroke. There are mainly two types of stroke conditions. Hemorrhagic and ischemic strokes are two different types of strokes brought on by bleeding in the brain.

Ischemic stroke, which makes up about 80% of all strokes, is the most frequent form. It happens when a blood clot or plaque accumulation restricts or plugs a blood vessel supplying the brain, causing blood flow to be reduced or stopped entirely. The brain is deprived of vital nutrients and oxygen due to this lack of blood flow, which harms the brain's cells. Thrombotic strokes, which happen when a blood clot forms in an artery supplying the brain, and embolic strokes, which take place when a blood clot or piece of debris travels from another region of the body and lodges in a brain artery, are two subtypes of ischemic strokes.

On the other hand, a hemorrhagic stroke is brought on by bleeding inside or outside the brain. It often happens when a blood artery is weakened due to excessive blood pressure or an

aneurysm rupture. The bleeding can harm brain tissue because it puts pressure on it. Hemorrhagic strokes fall into two categories: intracerebral hemorrhage, which involves bleeding inside the brain, and subarachnoid hemorrhage, which involves bleeding between the brain and the membranes that surround it.

1.1 COMPLICATIONS OF STROKE

A person may experience a variety of physical, cognitive, emotional, and psychological symptoms following a stroke. Depending on the location and severity of the stroke, several aftereffects may be experienced. Following are some typical stroke effects:

Physical Effects: The physical repercussions of a stroke can be severe and diverse, affecting a person's mobility and independence with daily activities. It can be difficult to walk, lift objects, or even perform basic self-care if a stroke survivor has weakness or paralysis on one side of their body (hemiparesis or hemiplegia), depending on the location and severity of the brain injury. Movements requiring precise control and stability may be challenging due to decreased coordination and balance. The capacity to feel touch or warmth might be impacted by sensory alterations in the affected limbs, such as numbness or tingling. Furthermore, weariness is a typical physical side effect of stroke that frequently lasts even with minimum effort. In treating these impacts, physical therapy is essential since it aids people in regaining their power.

Cognitive Effects Cognitive effects after a stroke can significantly impact a person’s thinking, memory, and ability to carry the activities in daily life. The patients may have trouble recalling recent events due to short- and long-term memory problems. Problem-solving, decision-making, planning, and organizing skills may be hindered by executive dysfunction. Aphasia, a disorder that impairs speech understanding, can result from conditions that influence language and communication ability. Cognitive performance may be hampered by visual issues such as

visual field impairments or issues with spatial perception. By using a variety of techniques and activities to boost memory, attention, language abilities, and other skills, cognitive rehab tries to address these consequences, allowing stroke survivors to regain independence and improve their quality of life.

Emotional and Psychological effects: following a stroke, emotional and psychological effects are common and can have a big impact on how effectively a person adjusts to life following the stroke. A wide range of feelings, such as despair, worry, and frustration, are frequently experienced by stroke survivors. Feelings of despair and hopelessness may be exacerbated by rapid changes in abilities, difficulties with daily tasks, and questions about the future. Anxiety disorders, such as post-stroke anxiety or generalized anxiety, can develop as a result of concerns about probable strokes in the future or changes in one's skills. It can also happen to have emotional lability, which is characterized by abrupt mood changes or fits of uncontrollable laughter or crying. It might be extremely difficult to deal with these emotional difficulties and adjust to your new situation after a stroke. Programs of rehabilitation that address the psychological effects of stroke, such as counseling and emotional support, are crucial.

1.2 CLINICAL PROBLEM

In the previous 17 years, the lifetime chance of suffering a stroke has climbed by 50%, and 1 in 4 people is now believed to experience one, according to the Global Stroke Factsheet issued in 2022. Between 1990 and 2019, there was a 70% increase in stroke incidence, a 43% increase in stroke-related deaths, a 102% increase in stroke prevalence, and a 143% increase in life years with disability-adjusted (DALY) [from the WHO report]. Ninety percent of stroke survivors

have a disability in one of their functions [1]. According to data revealing, 1.03 crore new stroke cases and 11.3 crore disability-adjusted life years (DALYs) annually, the burden of stroke is increasing globally. [2]. Eighty percent of stroke survivors are constrained by upper limb impairment, and just five to twenty percent make a full recovery [3].

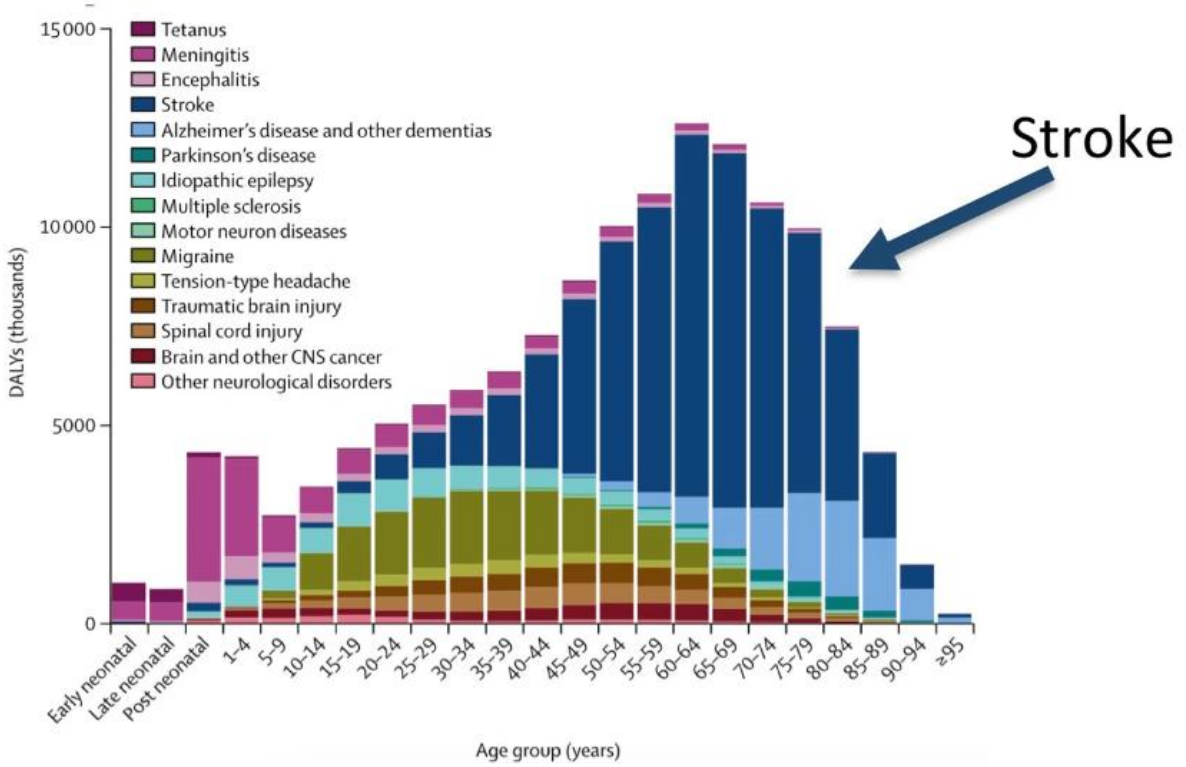

Fig 1.2: Disability Adjusted life years worldwide [12]

1.3 STROKE REHABILITATION

Rehabilitation is the primary method of treatment to lessen functional deficits following a stroke [4]. A crucial part of the recovery process for those who have had a stroke is stroke rehabilitation. It is a multidisciplinary strategy that strives to enhance and repair stroke-affected physical, cognitive, and emotional functions. Helping stroke patients regain independence, improve their quality of life, and maximize their functional capacities is the ultimate goal of stroke rehabilitation. Various rehabilitation strategies exist, including:

1.3.1 Conventional Rehab Techniques

Physical therapy: The primary component of stroke rehabilitation is physical therapy. It emphasizes enhancing flexibility, power, balance, and coordination. Physical therapists collaborate closely with stroke survivors to create individualized training regimens that concentrate on particular paralysis or weakness. These programs may include activities such as walking exercises, range-of-motion exercises, and strength training. Physical therapy can also involve the use of assistive devices like walkers or canes to aid in walking and restoring independence.

Occupational therapy: A vital part of helping stroke victims restore their capacity for performing activities of daily living (ADLs) and adjusting to any physical or cognitive restrictions brought on by the stroke is occupational therapy. Occupational therapists assist patients in creating self-care routines for activities including dressing, bathing, and eating. They may also offer instruction on how to use assistive technology or adaptive equipment to promote independence and enhance functional abilities in both the home and workplace both stability and coordination. Physical therapists collaborate closely with stroke survivors to create individualized training regimens that concentrate on particular paralysis or weakness.

Speech therapy: For stroke victims who have had trouble communicating and swallowing, speech therapy, or speech-language pathology, is crucial. Speech therapists assist patients in regaining their verbal communication abilities, including speaking, listening, reading, and writing. To enhance mouth and throat muscle control and coordination, they may employ a variety of methods and exercises. Speech therapists also deal with swallowing issues, offer methods to avoid aspiration, and guarantee secure eating and drinking.

Cognitive Rehabilitation: The goal of cognitive rehabilitation is to treat cognitive impairments brought on by a stroke, such as memory loss, attention issues, and difficulty solving problems. Cognitive therapists use a variety of methods and activities to enhance cognitive function and aid stroke victims in regaining their capacity for thought, reasoning, and decision-making. These could involve training for attention, problem-solving, and memory.

Fig 1.3: Tools Used in Conventional Rehab Techniques

1.3.2 Limitations

Although conventional rehabilitation plays an important role in helping individuals recover after a stroke it still has certain drawbacks that are worth considering:

Limitation of time and access: The amount of time a patient can undergo therapy is usually limited by the fact that traditional stroke rehabilitation frequently takes place in a hospital or clinic. Sessions might only last a few hours a week because of time restraints, which would lower the therapy's total intensity and frequency. The possibility of an ideal recovery may be hampered by this restricted access.

Transferring Learned Skills and Methods to Real-World Tasks Can Be Difficult: Traditional rehabilitation may not place enough emphasis on applying Learned Skills and Strategies to Real-World Tasks. Patients may find it difficult to integrate their rehabilitation progress into daily activities, which will hinder their capacity to reclaim their independence and rejoin society.

Emotional and psychological factors: The difficulties that stroke survivors confront on an emotional and psychological level may not always be appropriately addressed by traditional stroke therapy. Recovery may be hampered by problems including depression, anxiety, and lack of motivation. A holistic strategy that addresses both physical and mental well-being is essential for thorough stroke therapy. Only 31% of patients perform the exercises, despite research suggesting that many patients may heal by performing 100 repetitions of motion with their damaged limbs each day. Due to these reasons nowadays advanced rehabilitation techniques have gained importance in the medical rehabilitation sector.

1.3.3 Advanced Rehab Techniques

Advanced stroke rehabilitation procedures include a variety of cutting-edge methods that work in conjunction with conventional treatments to improve recovery times. Here are a few instances of cutting-edge rehabilitation methods applied in stroke recovery:

Robotics and Exoskeletons: Exoskeletons and robotic gadgets can help stroke victims restore their motor skills. To promote motor relearning and muscle activation, these technologies offer repetitive, task-specific movements. They can be configured to respond to each user's demands, providing individualized therapy and timely performance feedback.

Virtual Reality and Augmented Reality: The use of VR and AR technologies in stroke rehabilitation is growing. They design interactive, immersive settings that let stroke victims participate in virtual activities and realistic situations. Through the use of these technologies, therapy sessions can be made more engaging and pleasant while also enhancing motor skills, balance, and coordination.

Functional Electrical Stimulation (FES): Electrical currents are used in FES to activate weak or paralyzed muscles, causing muscular contractions and enabling useful movements. To increase independence and mobility for stroke survivors, FES can aid with muscle strength, coordination, and walking ability.

Mirror Therapy: Mirror treatment includes utilizing a mirror to make the damaged limb appear to move. The brain can detect movement in the injured limb by visualizing the mirrored image of the unaffected limb moving, which encourages neuronal activity and motor recovery. In stroke rehabilitation, mirror treatment has demonstrated beneficial effects on motor function and pain control.

Through continued study and technological developments, these cutting-edge rehabilitation procedures are always changing and being improved. Even though they present intriguing opportunities, stroke rehabilitation must be individualized for each patient and overseen by qualified healthcare experts to ensure safe and efficient implementation.

Fig 1.4: Advanced Rehab Techniques

1.3.4 Advantages

Advanced stroke rehabilitation approaches come with several benefits that could speed up recovery and improve outcomes for stroke victims. Among the principal benefits are:

Targeted and Intensive Therapy: Robotics, virtual reality, and brain-computer interfaces are examples of cutting-edge technologies that enable precise and targeted therapy. They can concentrate on particular impairments, offering intensive, repetitive training that is catered to the needs of the person. This focused approach can hasten recovery and encourage more effective brain reorganization.

Increased Engagement and Motivation: Advanced rehabilitation methods sometimes include immersive and interactive components, such as gamification and virtual worlds. These appealing elements can encourage stroke victims to actively engage in therapy sessions, encouraging higher effort and adherence to the rehabilitation program. These treatments' entertaining and stimulating qualities can help lessen the frequent boredom and frustration associated with standard therapy, making the recovery process more joyful.

Enhanced Neuroplasticity: The term "neuroplasticity" describes the brain's capacity to reconfigure and create new connections after suffering damage. Brain stimulation and other

innovative techniques, such as constraint-induced movement therapy, can promote neuroplastic changes by stimulating certain brain regions or by encouraging the use of damaged limbs. These treatments aid in the facilitation of functional recovery and the promotion of brain circuit remodeling.

Real-time Feedback and Monitoring: Many advanced techniques provide real-time feedback on performance, enabling stroke victims and therapists to track development and make necessary adjustments. This feedback facilitates faster adjustments and enhances motor learning. Additionally, the capacity to monitor and assess development over time might offer factual information for target-setting and treatment planning.

In conclusion, stroke rehabilitation is a thorough and multidisciplinary strategy that tries to help stroke victims regain their physical, mental, and emotional abilities. Stroke survivors can significantly improve their independence and quality of life with physical treatment, occupational therapy, speech therapy, cognitive rehabilitation, and psychological support. The success of stroke therapy is increased and long-term recovery is promoted by family and carer involvement, ongoing practice, and support. Rehabilitation is essential to the recovery process following a stroke. Through physical therapy, occupational therapy, speech therapy, and other specialized interventions, rehabilitation programs assist stroke survivors restore lost functions and relearn skills. Enhancing mobility, strengthening speech and language, and addressing cognitive deficits are the objectives. To lower the risk of future strokes, it is also important to prevent them. Stroke prevention entails addressing underlying illnesses like high blood pressure and diabetes as well as pursuing a healthy lifestyle that includes regular exercise, a nutritious diet, and quitting smoking.

CHAPTER 2

LITERATURE REVIEW

Feigin VL, Stark BA et. al [5] - According to the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2017, stroke was the world's second-leading cause of death and the third-leading cause of death and disability combined. According to a GBD 2017 stroke review, whereas age-standardized stroke fatality rates dropped significantly between 1990 and 2017, the decline in age-standardized incidence was far less pronounced, suggesting that prevention measures have been less effective than those aimed at treating the condition. The findings from GBD 2016 showed that a significant portion of the DALYs from both ischemic and hemorrhagic strokes was attributable to potentially modifiable risk factors evaluated in GBD, suggesting the possibility of lowering the burden of stroke through lower risk factor exposure. Similar to the findings from GBD 2016 and GBD 2017, the WHO states that effective stroke preventive techniques include lowering the risk associated with hypertension, high lipids, diabetes, smoking, low physical activity, unhealthy diet, and abdominal obesity. This study calculated the incidence, prevalence, mortality, and disability-adjusted life years (DALYs) associated with stroke-related risk variables associated with 19 potentially modifiable risk factors or combinations of risk factors.

Langhorne P, Bernhardt J et. al [6]- Stroke is a prevalent, dangerous, and incapacitating health issue on a global scale. Although there have been notable advancements in the medical therapy of stroke, the majority of post-stroke care will still rely on rehabilitation treatments because there is no medical treatment that is both widely applicable and successful. The evidence supporting stroke rehabilitation, including the guiding principles of rehabilitation practice, care

delivery systems, and particular therapies, is the main emphasis of this review. The study also addresses the most frequently asked questions by doctors on the outcomes of therapies for stroke-related impairment and disability. The majority of research on stroke rehabilitation has focused on how interventions affect recovery from various types of impairment and disability. The main topic of the study is stroke rehabilitation, which includes the fundamentals of rehabilitation practice, care delivery systems, and particular therapies. The following are the paper's contributions: providing information about stroke rehabilitation that is supported by evidence, examining the results of therapies for stroke-related disability and impairment, highlighting possible effective therapeutic alternatives for gait and arm motor rehabilitation, recognizing the lack of knowledge regarding the clinical impact of different cognitive rehabilitation treatments and strategies for aphasia and dysarthria, Conducting continuing, extensive studies of novel therapies and rehabilitation techniques to help guide future practice.

Sisto SA, Forrest GF et. al [7] – the paper states the ability of virtual reality (VR) to govern interaction without the limitations of computer systems, according to the paper it has the potential to have a substantial influence on motor rehabilitation following stroke. To properly assess the potential of VR motor skill training and its efficiency in translating the trained task to the same or similar real-world activities, however, objective studies are necessary. The study explores the potential of virtual reality (VR) for stroke motor rehabilitation and emphasizes. Future research should, according to the article, concentrate on the following areas: doing impartial research to thoroughly assess VR's potential for motor retraining, examining the value of VR training as an addition to the regular practice as opposed to a replacement, investigating how VR and rehabilitation might be combined for motor retraining, designing VR movement-optimization methods, Recognizing the risks and challenges that may arise because to our inadequate knowledge of the neurological rehabilitation of mobility, the necessity for thorough

studies to assess its efficacy. Additionally, it emphasizes how crucial interdisciplinary cooperation is to the effective application of VR for motor retraining. Consequently, the following are the primary contributions of this paper: highlighting VR's potential for stroke-related motor rehabilitation, and recognizing the requirement for impartial research to gauge the success of VR motor skill training, putting a focus on the necessity of interdisciplinary cooperation for the effective application of VR for motor retraining.

. Baniasadi T, Ayyoubzadeh SM et. al [8] - This study outlines the general difficulties in implementing VR-based rehabilitation procedures, including diminished face-to-face interactions, financial constraints, and issues with user attitudes and education. the specific challenges in implementing VR like designing, the level of immersion, appropriate use of tracking and vision systems, facilitating installation and operation, etc are portrayed. typical adverse consequences Potential VR adverse effects have been listed as cyber sickness and perceptuomotor aftereffects. In actuality, simulated sickness, or cybersickness, is the biggest worry for VR consumers. Long-term use of VR systems can also cause headaches and eye strain. Similar to motion sickness, cybersickness (such as nausea, vomiting, eye fatigue, dizziness, ataxia, dizziness, etc.) is a result of sensory input inconsistencies that cause a conflict between various body sensory systems. Some examples of cybersickness continue, such as when the user is flying in a virtual airplane while the user's actual gravity contrasts with the world being observed.

Saeedi S, Ghazisaeedi M et.al [1] - The study in the publication is a systematic review that was carried out using the PRISMA methodology. To find relevant papers, the authors carried out a thorough search of PubMed, Scopus, IEEE Xplore Digital Library, and ISI Web of Science from January 1, 2014, to November 9, 2020. The article examined 60 studies that used

recently developed games for post-stroke patients' physical rehabilitation. The most widely used form of physical therapy for post-stroke patients was virtual reality-focused games, with "The Nintendo Wii Fit" game being used more frequently than other games. Only three studies found the used games to be ineffective, according to the evaluation results of the games. Other research found that playing games had positive effects on the target body parts. The findings show that contemporary games are effective in post-stroke patients' physical rehabilitation and can be utilized in conjunction with traditional approaches. The study contends that contemporary games can complement traditional therapies and are effective for post-stroke patients' physical rehabilitation. The study emphasizes how games can complement therapeutic exercises, create a fun environment for patients, and improve treatment compliance.

Tuah NM, Ahmedy F et. al [9] - To boost patient motivation and participation in particular types of rehabilitation training, rehabilitation needs engaging tools. Adopting gamification in rehabilitation can provide various contexts for treatment and care when putting rehabilitation training into practice. Variable gamification methods have been used in health applications and can produce a variety of gameplay impacts. There are, however, few studies that look into the gamification of rehabilitation and appropriate gaming techniques for rehabilitation. Examining and analyzing current gamification methods for rehabilitation applications is the goal of this article. Based on the need for rehabilitation gamification and often used gamification characteristics in rehabilitation applications, the research creates a taxonomy of rehabilitation gamification. The paper portrays exploring current gamification applications in therapy creating a taxonomy of gamified rehabilitation applications, including computer and mobile applications locating and assessing rehabilitation-related gamification applications analyzing key issues with gamification applications in rehabilitation, and identifying future e-health research prospects. It can be concluded that gamification is a useful technique for boosting

motivation and engagement in rehabilitation training. The classification of gamification applications in rehabilitation provided in this study can be utilized as a template for creating and implementing game-like experiences for healing during rehabilitation. According to the data, the most frequently used domain for applying the gamification strategy to enhance rehabilitation outcomes is physical therapy, particularly hand, and upper limb rehabilitation. The most well-liked gamified application types also include robot-based and mixed-reality implementations. The report also highlights several issues and areas for future research to enhance the use of gamification in rehabilitation.

Wannenburg J, et .al [10] - The approach described in the study uses machine learning algorithms and accelerometer data from smartphones to categorize physical activities. The best classifier algorithm for recognizing physical activity is investigated in this research along with its implementation. The research compares the performance of different classifier systems for identifying physical activity. In this study, physical activity recognition for routine behaviors such as sitting, standing, lying down, walking, and jogging was carried out. Smartphone accelerometer data was used to get the information for activity recognition. Accelerometers are sensors that track an object's motion and orientation changes by measuring its acceleration. The use of smartphone accelerometer data allowed the paper to correctly identify common physical activities like sitting, standing, lying down, walking, and jogging. On a remote server, machine learning methods were used to classify the activities. The most accurate model was discovered to be the KNN method. The provided method is dynamic and is easily adaptable to alternative accelerometer hardware or to other activity detection, such as stair climbing and fall detection. The article concludes that offline activity recognition could be predicted with high accuracy.

Choi YH, Ku J, et. al [11] - In this study, a mobile VR game-based rehabilitation program for the upper extremities was created. The program was created to aid stroke victims in regaining upper extremity function. The study's conclusions demonstrate how the mobile game-based

VR program efficiently encourages stroke patients' recovery of their upper extremities. Patients used the program for two weeks of treatment without experiencing any negative side effects, and they were generally happy with it. The VR upper extremity rehabilitation program for mobile devices can replace some of the traditional therapy sessions that are conducted one-on-one by an occupational therapist. This method is quick, simple to use, and clinically successful. The program would be a suitable candidate for a telerehabilitation tool to help stroke victims regain the use of their upper extremities. Through these e-health rehabilitation programs, patients and therapists can communicate virtually and cut financial and social costs.

2.1 OBJECTIVES

The following are the objectives of the study:

1. The purpose of the study is to check the feasibility of introducing gamification in the field of stroke rehabilitation.
2. Design a game for improving upper extremity hand rehabilitation.
3. To compare the finger movements in real life to that in the gamified application.

CHAPTER 3

METHODOLOGY

Initially, rehabilitation biomechanics is selected as the focus area. Rehabilitation biomechanics is an interdisciplinary field that incorporates ideas from biomechanics and rehabilitation sciences. It entails the investigation of human movement as well as the mechanics and forces at play during motor functions. Rehabilitation specialists can better understand the underlying causes of impairments, create focused therapies, and improve the results of rehabilitation by looking at the biomechanical components of movement. The goal of rehabilitation biomechanics is to improve the comprehension and use of movement analysis and therapy in rehabilitation settings. The topic of choice is gamification in healthcare, which involves providing fun technologies to boost patients' motivation and involvement in specific types of rehab programs.

3.1 ARTICLE DISTRIBUTION OF GAMIFICATION APPLICATION IN REHAB PRACTICES

Fig.3.1 emphasizes that gamification's prevalence in rehabilitation techniques shows that it may be used to improve both physical and psychological recovery. Gamification is the process of integrating game principles and aspects into environments that are not games to increase participation, motivation, and engagement. Gamification can be used in physical rehabilitation to make rehabilitative exercises and activities more fun and engaging. Patients are more likely to remain interested and motivated when workouts are made to resemble games, which boosts

adherence and improves results. For instance, a virtual reality game might be created to imitate movements that correspond with particular physical therapy exercises, giving patients a more engaging and immersive experience.

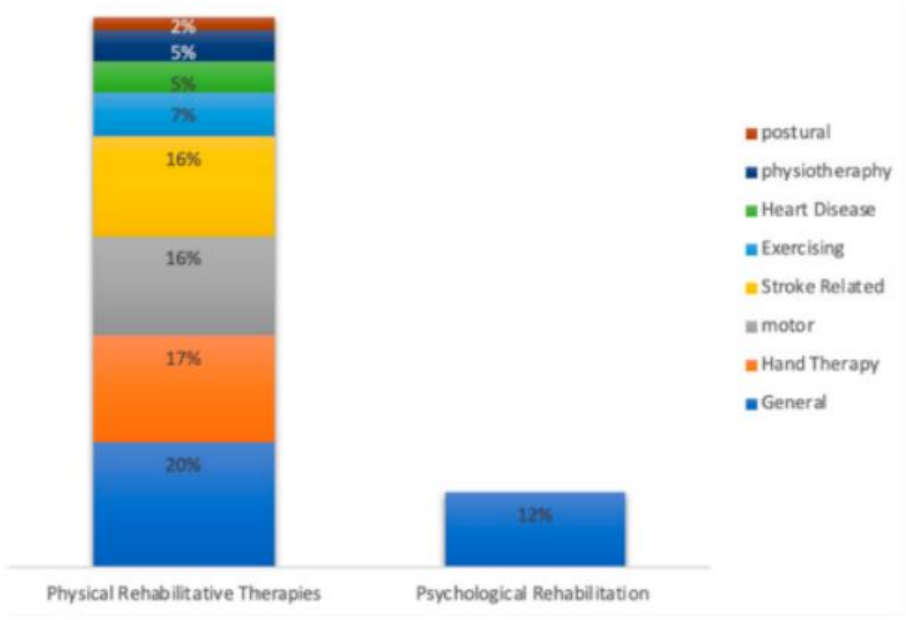

Fig 3.1: Article Distribution of gamification application [9]

In psychological rehabilitation, gamification can be applied to various therapeutic interventions. It can assist people with mental health issues, such as depression or anxiety, in participating in activities that support emotional well-being. Gamified therapies can offer an organized and engaging method of addressing emotional and cognitive difficulties. Based on the knowledge that motivation and engagement are essential components for good rehabilitation outcomes, gamification is being used in both physical and psychological rehabilitation. Gamification can tap into innate motivations and improve the entire rehabilitation experience by including game components like incentives, competition, progress tracking, and social interaction. For our study, we select physical rehabilitation as a rehabilitative sector for the application of gamification because it has the potential to enhance motivation, engagement, accessibility, and customization in therapy programs.

3.1.1 Survey

To find out whether we can introduce gamification in physical rehabilitation a primary survey was conducted among physiotherapists and clinicians. From the survey, it was found that gamified interventions can be introduced in the field of rehabilitation. The possibility to increase patients' confidence is one of the main advantages of gamification in healthcare. Exercises used in traditional rehabilitation can occasionally become tedious and repetitious, which lowers motivation and involvement. Patients are more likely to feel a sense of accomplishment and satisfaction during their rehabilitation process by including gamification components, such as game-like tasks, prizes, and progress tracking. As patients see their advancements and successes within the gamified system, this pleasant experience might help patients feel more confident.

Gamified therapies also have the benefit of increasing the number of exercise repetitions. To rebuild strength, flexibility, or motor abilities, rehabilitation frequently calls for patients to continuously perform certain motions or exercises. But for some patients, maintaining these repetitions can be difficult, especially if they find the exercises boring or exhausting. Gamification offers the chance to make these workouts into lively and participatory tasks. Patients are more prone to remain motivated and dedicated to completing the required repetitions if game aspects, such as goal-setting, levels, or rewards connected to exercise completion, are included in the exercise program. As a result, this may produce better and more rehabilitation results.

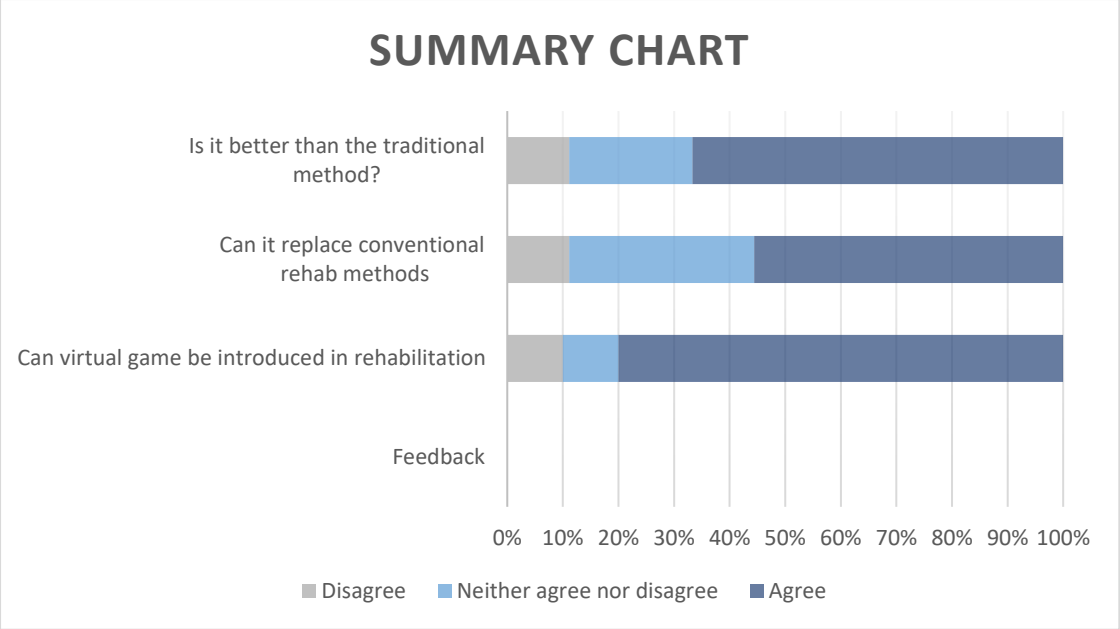

Fig 3.2: Survey chart

In conclusion, the results of the primary survey among physiotherapists and clinicians indicate that implementing gamification in rehabilitation can have several advantages. By giving them a sense of accomplishment and satisfaction, it can boost patients' confidence. By including game-like aspects, it can also increase the number of repetitions of exercises. These benefits show that gamified therapies have the potential to enhance patient involvement and results in the field of rehabilitation.

3.2 SELECTION OF MEDICAL CONDITION

Rehabilitation can be referred to as the process of restoring and enhancing a person's functional, mental, and physical capacities after an illness, injury, or handicap. It is a multidisciplinary strategy with the goals of assisting patients in regaining their independence, enhancing their quality of life, and reintegrating into society. Many medical conditions could call for rehabilitation as part of the therapy strategy. Here are some examples of these conditions: Stroke, Traumatic Brain Injury, Spinal Cord Injury, Cerebral Palsy, Musculoskeletal Injuries, etc. Initially, two medical conditions are selected: Neurological and Orthopedic conditions.

3.2.1 Neurological Condition

Neurological conditions refer to a wide variety of ailments that affect the brain, spinal cord, and other central nervous system components. Numerous factors, including heredity, infections, autoimmune reactions, traumatic accidents, or degenerative processes, can contribute to the development of these disorders. The normal operation of the nervous system is frequently disrupted by neurological diseases, which can cause a wide range of symptoms and impairments. Some of the neurological conditions are stroke, multiple sclerosis, Parkinson’s disease, Cerebral palsy, Alzheimer’s disease, etc. We consider only two neurological conditions: stroke and cerebral palsy.

Stroke: A stroke is a neurological event that happens when the blood supply to the brain is compromised, it can cause damage to brain cells. It can result in a variety of neurological symptoms due to a blocked or ruptured blood vessel. These could include cognitive problems, loss of coordination, paralysis or weakness on one side of the body, trouble speaking or interpreting speech, and difficulties communicating.

Cerebral Palsy: A collection of neurological conditions known as cerebral palsy mainly impact mobility, muscle tone, and coordination. It is brought on by harm to the developing brain, which frequently takes place before, during, or after birth, or in early infancy. Spasticity, involuntary movements, poor coordination, and balance issues are just a few examples of the motor impairments brought on by cerebral palsy-related brain injury or abnormal brain development. Cerebral palsy can range in severity and affect each person differently, necessitating individualized care and rehabilitation strategies to enhance motor skills, mobility, and functional abilities and enable people with cerebral palsy to lead as normal a life as possible.

3.2.2 Orthopaedic Condition

Orthopedic disorders cover a broad spectrum of musculoskeletal illnesses that affect the bones, joints, muscles, ligaments, tendons, and other tissues important for the movement and support of the body. These disorders can be brought on by several sources, such as trauma, aging processes, genetics, or underlying medical conditions. Orthopedic problems can result in discomfort, restricted movement, and functional limitations. Here are a few common examples: Osteoarthritis, Fractures, Tendinitis, Scoliosis, frozen shoulder, Carpal Tunnel Syndrome, etc. We consider only consider frozen shoulder.

Frozen Shoulder: Orthopaedic conditions include frozen shoulder, often known as adhesive capsulitis. It is characterized by shoulder joint stiffness and pain, which limits the range of motion. Although the specific origin of a frozen shoulder is unknown, it is thought to entail inflammation and thickening of the shoulder joint capsule, which restricts the joint's range of motion. The three stages of a frozen shoulder often occur gradually and include the following symptoms: greater pain and stiffness, prolonged stiffness with diminished discomfort, and

progressive improvement in range of motion. It can happen on its own or as a result of some risk factors, like diabetes, shoulder injuries, or extended immobilization.

According to the survey, the majority of physiotherapists believe that stroke therapy is the greatest area for gamification to be applied.

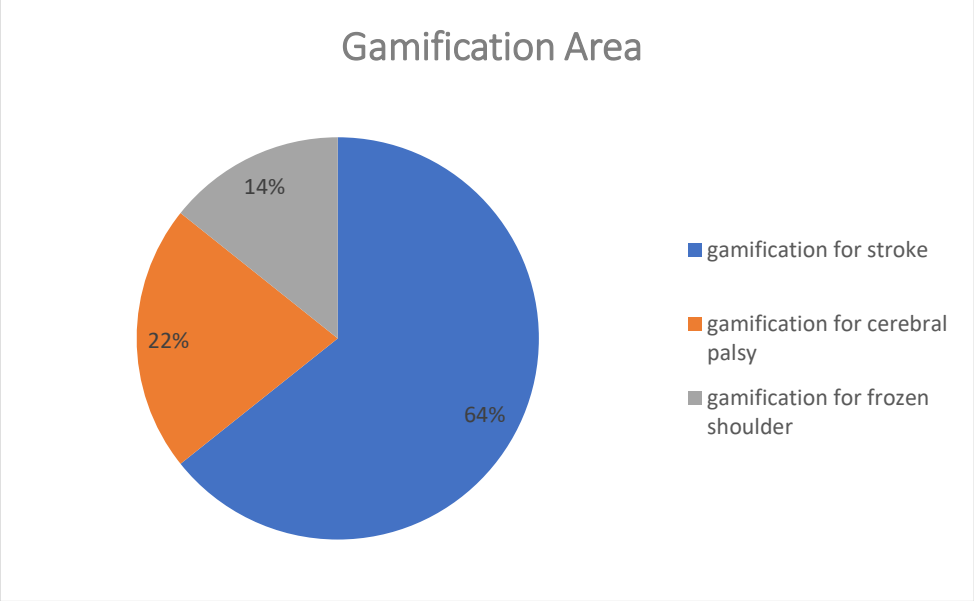

Fig 3.3: Gamification Area

Virtual game-based therapy has shown benefits for stroke recovery for several reasons:

Stroke rehabilitation is often viewed as a relearning process since it entails assisting people in regaining skills and capacities that the stroke may have damaged; stroke rehabilitation is frequently seen as a relearning process. After a stroke, key regions of the brain that are in charge of movement, speech, cognition, and other processes stop working as they should. Rehabilitation is done to regain the lost skills which the patients already knew through certain techniques. The brain can reorganize and form new connections, known as neuroplasticity. Stroke rehabilitation takes use of neuroplasticity by offering targeted, intense therapy to

support the brain's capacity for relearning and adaptation. This could entail exercises, daydreaming, and useful tasks that encourage neuronal remodeling.

Task-Specific Training: Patients practice activities related to their specific problems repeatedly and intentionally. For instance, a patient who has trouble walking might take part in gait training exercises to retrain and enhance their walking abilities.

Cognitive Rehabilitation: For those who have suffered a stroke and have cognitive deficits, cognitive rehabilitation aims to retrain mental skills like memory, focus, problem-solving, and executive functioning. This process of relearning aids people in regaining cognitive abilities and improving their capacity to carry out daily chores.

The reason for which gamification is difficult in cerebral palsy and frozen shoulder is that; cerebral palsy is a learning process in which the patients are learning and acquiring new movement coordination skills despite existing challenges or impairments. Movement and muscular coordination are affected, which frequently results from brain injury or faulty brain development. As a result, people with cerebral palsy could struggle with their coordination, muscular tone, and motor function. For frozen shoulder patients, virtual game-based rehabilitation can present challenges due to several factors; it has a restricted range of motion in the shoulder joint and is characterized by stiffness. Virtual games sometimes call for a variety of arm motions and movements, which can be painful or difficult for people with frozen shoulders to complete. It could be difficult to get involved in the game and execute the necessary movements precisely due to the restricted range of motion. Pain and discomfort in the afflicted shoulder are common symptoms of a frozen shoulder. Virtual games with demanding or repeated arm movements may make it more painful and uncomfortable for players, limiting their ability to fully engage in or enjoy game-based therapy.

3.3 MAPPING OF GAMIFIED INTERVENTIONS

Different gamified strategies can be employed in stroke therapy to improve the healing process. These interventions use the mechanics and components of games to increase the motivation, engagement, and efficiency of therapy. Choosing the kind of gamified intervention for the study is the next stage.

Table 3.1 Mapping of gamified intervention [9]

DOMAIN	SUB DOMAIN	GAMIFIED TYPE OF INTERVENTION
General Stroke Rehabilitation	Improve muscle strength	Gamified robot-based system
	Improve motor coordination	VR/AR assisted game system
	Improve mobility and movement	Games played using a smartphone sensor, Games played using Microsoft Kinect
Hand Rehabilitation (Upper limb rehabilitation)	Motor recovery, improve mobility	AR/VR assisted game system, game played using smartphone sensor
	Improve motor control	Games played using Microsoft Kinect
	Improve muscle strength	Robot-based system
Neurological Rehabilitation	Improve mobility and movement	VR/AR assisted game system
	Reduced concussion	Mobile social gamified apps
Gait Rehabilitation	Improve movement	AR/VR-assisted game system
Psychological Rehabilitation	Improve quality of life	A gamified mobile e-health application

Virtual reality (VR) games: VR games offer an immersive and participatory experience. Virtual reality (VR) games can be created to replicate everyday actions like reaching, gripping, and walking in stroke therapy. Patients can participate in these virtual exercises, which can enhance balance, coordination, and motor skills while also offering a fun and stimulating experience.

Motion-Capture Games: Gamified therapy for stroke rehabilitation can make use of motion-capture technologies. Patients can interact with virtual games or avatars by wearing sensors or using motion-capture equipment that tracks their motions in real time. These video games frequently concentrate on particular exercises or movements, offering visual feedback and prizes based on the patient's movements' precision and calibre.

Exergames: Exergames incorporate physical activity into gameplay by combining workout and gaming aspects. Motion-sensing devices, including cameras or sensors, are frequently used in these games to monitor the patient's movements. Exergames encourage physical activity, motor function, and cardiovascular fitness in stroke therapy by translating exercises into interactive, game-like tasks.

Serious Games: Serious games are made primarily for goals other than pure amusement, frequently for educational or therapeutic ones. Serious games can be created to target particular therapeutic objectives in stroke rehabilitation, like motor control, cognitive training, or daily living activities. These games offer enjoyable and difficult activities that promote practice and advancement in specific areas.

We are focusing on stroke rehabilitation using smartphone sensors. The use of smartphone sensors for stroke rehabilitation is a cutting-edge strategy that makes use of the devices' in-built sensors to monitor and support the healing process. Various sensors, including accelerometers, gyroscopes, magnetometers, and touchscreens, are included in modern smartphones. These sensors can be used to measure motions, collect data, and offer feedback during rehabilitation activities. Smartphone touchscreen sensors can be used to identify particular motions made by the patient. As a result, gesture-based rehabilitation apps can be created that prompt the user to execute particular exercises or movements. The patient's motions can be detected and analyzed by the smartphone, which can then give immediate feedback on how accurate and precise their movements were.

3.4 REHABILITATION TECHNIQUE

Exercises of all kinds are used in stroke therapy to assist patients to rebuild strength, to increase mobility, and to improve overall function. These exercises can be divided into three categories: muscle-strengthening, passive, and active.

Passive Exercises: In passive exercises, the patient's injured limb or body part is moved for them by a therapist or carer without their active participation. In the early stages of stroke recovery, when the patient may have little voluntary movement, these activities are frequently carried out. Exercises done passively support circulation, prevent muscular stiffness and preserve a range of motion. Gentle stretching, range-of-motion exercises, and passive joint mobilization are a few examples of passive exercises.

Active Exercises: In an active exercise, the person actively moves the limb or body part that is injured without help. With the help of their muscles, the patient is encouraged to engage fully in the healing process through these exercises. Muscle control, coordination, and total functioning abilities are all enhanced by engaging in active activities. Active range of motion exercises, reaching and grasping exercises, and repetitive functional movements are a few examples of active exercises.

Exercises to Strengthen Muscles: Exercises to Strengthen Muscles are designed to increase the strength and endurance of the muscles in the limb or body part that is injured. These activities aid in the recovery of muscle mass and improve force production, both of which are frequently impaired after a stroke. Depending on the person's ability, muscle-strengthening exercises can be done with resistance bands, weights, or only body weight. Resistance training, isotonic workouts, and weight-bearing activities are a few examples of exercises for strengthening muscles. The gamification application can be incorporated into active range exercises, which are ones in which the patient can move the injured limb on their own without the assistance of another person or any external force.

3.4.1UPPER EXTREMITY REHABILITATION

One of the after-effects of a stroke is paralysis, usually after a stroke patient suffers from hemiplegia in which affects one side of the body and is usually caused by damage to the brain on the other side. So, both the lower and upper extremity requires rehabilitation. For, our study we are considering upper extremity rehabilitation.

Stroke rehabilitation for the upper extremities concentrates on regaining function and enhancing motor abilities in the arm, hand, and shoulder. To promote independence in daily activities, the aim is to regain mobility, strength, and coordination. The following are some prevalent strategies and treatments applied to the rehabilitation of upper extremity stroke:

- Range of Motion Exercises: Exercises that increase the range of motion can assist the afflicted arm and shoulder to remain flexible and mobile or get back to being mobile. The joints are gently stretched and moved during these workouts to prevent stiffness and contractures.
- Strengthening Exercises: To increase muscle strength and endurance in the afflicted upper extremity, strengthening exercises are performed. They could include resistance exercises using weights, resistance bands, or specialized apparatus. Depending on the person's specific limitations and objectives, various muscle groups are targeted.
- Constraint-Induced Movement Therapy (CIMT) is a type of movement therapy that involves restraint of the unaffected arm while vigorous therapy with the affected arm. This method tries to promote motor recovery and functional benefits by encouraging usage and retraining of the afflicted limb.
- Mirror Therapy: Mirror therapy uses a mirror to reflect the unaffected limb, giving the impression that the affected limb is moving. This method enhances body awareness, coordination, and motor control. To stimulate the brain's perception of movement in the

damaged limb, patients make symmetrical movements with the unaffected limb while watching the reflection.

- Electrical Stimulation: To promote muscle activation and improve weak muscles, electrical stimulation may be utilized as an additional therapy. It entails delivering mild electrical currents to the injured muscles to encourage muscular contractions and improve motor rehabilitation.

In upper extremity rehabilitation, we are focusing on hand rehabilitation in which the finger movements are considered. The goal of hand rehabilitation is to enhance finger movements while regaining finger dexterity, strength, and coordination. For many daily actions, including gripping items, using tools, and completing fine motor tasks, finger movements are essential.

3.4.2 HAND REHABILITATION

To improve stroke patients' mobility, a variety of finger rehabilitation techniques and methods are used. Here are a few current methods:

Exercises for Passive Range of Motion (PROM): In passive range of motion exercises, the fingers and joints of the injured hand are softly moved through their full range of motion by a therapist or caretaker. This promotes circulation, prevents contractures, and preserves joint flexibility. When active movement may be restricted in the early phases of rehabilitation, PROM exercises are frequently carried out.

Exercises that promote active range of motion (AROM): AROM exercises encourage stroke patients to move their fingers and joints on their own without assistance. These movements enhance mobility, enhance coordination, and encourage voluntary muscular activation. The

movements of the fingers are guided through flexion, extension, abduction, and adduction in patients.

Exercises for Finger Extension: Patients with stroke frequently have stiffness in their finger flexors, which results in flexed fingers. To reduce this spasticity, finger extension exercises concentrate on gradually stretching and extending the fingers. To enhance finger extension, strategies like passive stretching, splinting, and tendon gliding activities may be performed.

Mirror Therapy: In mirror therapy, the unaffected hand is reflected in the mirror to give the impression that the affected hand is moving. The patient carries out mirror-matching drills while synchronizing the motions of both hands. This method enhances finger mobility, coordination, and motor control.

Exercises and interventions for hand rehabilitation are adapted to the unique impairments, objectives, and progress of the individual. The direction and customization of the rehabilitation program are greatly aided by occupational therapists, hand therapists, or physical therapists with a focus on hand rehabilitation. For finger-focused hand rehabilitation to be successful, constant practice, repetition, and a progressive increase in difficulty are necessary.

3.5 REHABILITATION BIOMECHANICS

The study of the enhancement of human movement and function throughout the rehabilitation process is the focus of the area of rehabilitation biomechanics, which applies biomechanics concepts to this subject. It focuses on comprehending the mechanical components of human motion, examining movement patterns, and developing interventions to improve mobility and improve the results of rehabilitation.

Finger rehabilitation biomechanics focuses on the use of biomechanical concepts, in order to enhance the movement, strength, coordination, and function of the fingers during the rehabilitation process. To maximize finger rehabilitation, it entails examining the biomechanics of finger movements, spotting impairments or constraints, and creating focused therapies. In many daily activities and while performing tasks that call for dexterity, precision, and fine motor control, finger movements are crucial. Finger movements need complex coordination and control between numerous muscles, tendons, joints, and sensory input. The following are some essential finger motions:

Finger Flexion and Extension: The basic movements of the fingers are finger flexion and finger extension, which include bending (flexion) and straightening (extension) at the joints. These motions are essential for many daily jobs and those that call for fine motor control.

Flexion: In order to flex, the fingers must be bent inward and towards the palm of the hand, lowering the angle between the finger segments (phalanges) and bringing them closer together. The fingers' metacarpophalangeal (MCP), proximal interphalangeal (PIP), and distal interphalangeal (DIP) joints are where flexion primarily takes place. Flexing the fingers is necessary for holding things, clenching your hand, typing on a keyboard, playing musical instruments, and carrying out many other fine motor tasks. According to the American Academy of Orthopedic Surgeons, the normal range of finger movements is 86°(index), 91° (ring), and 105° (little), and from the American Medical Association, the normal range is 90°.

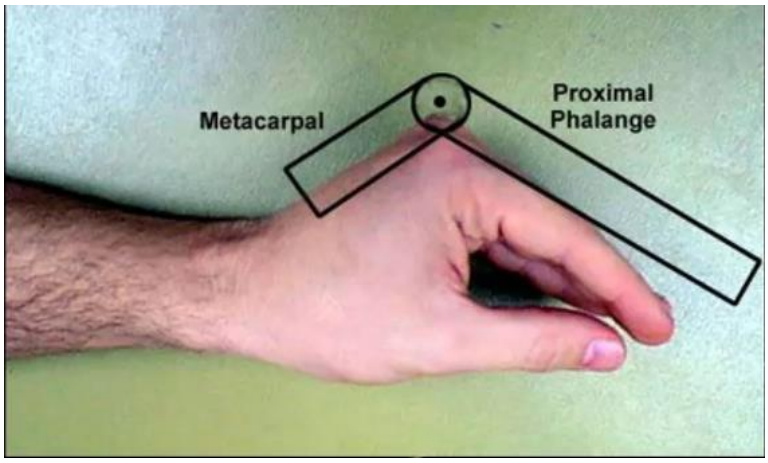

Fig 3.4: Finger Flexion

Finger Extension: Extension refers to straightening the fingers, returning them to their neutral or extended position, and increasing the angle between the finger segments. The forearm extensor muscles, such as the extensor digitorum communis (EDC) and the extensor indicis proprius (EIP), are principally in charge of extending the fingers. The finger MCP joints, PIP joints, and DIP joints are where extension mostly happens. Finger extension is essential for reaching, opening the hand, releasing things, and performing other actions that call for fine control and finger separation. According to the American Academy of Orthopedic Surgeons, the normal range of finger movements is 22°(index), 23° (ring), and 19° (little), from the American Medical Association, the normal range is 20°.

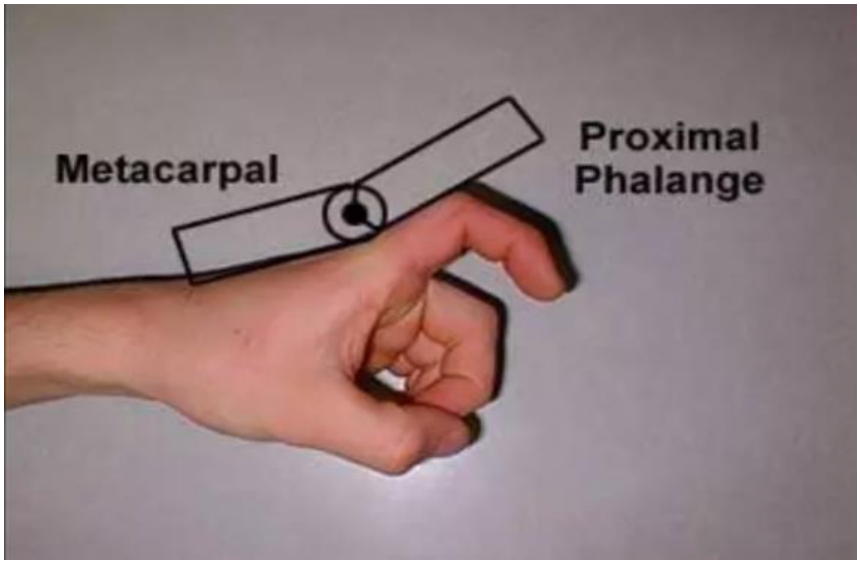

Fig 3.5: Finger Extension

Finger adduction and abduction: The actions of finger adduction and abduction include drawing the fingers closer together (adduction) or further apart (abduction). These motions are necessary for using the hands for a variety of tasks, including gripping and precise object manipulation.

Finger Adduction: Adduction is a way of moving the fingers closer together, either towards the middle finger or the midline of the hand. The interossei and lumbrical muscles, which are found in the hand, are the main muscles in charge of finger adduction. Metacarpophalangeal (MCP) and proximal interphalangeal (PIP) joints in the fingers are where adduction primarily takes place. When executing fine motor actions that call for accuracy and finger control, such as grasping objects, holding a pen or utensil, and gripping, finger adduction is crucial. According to the American Academy of Orthopedic Surgeons, the normal range of finger movements is 0° or usually not measured.

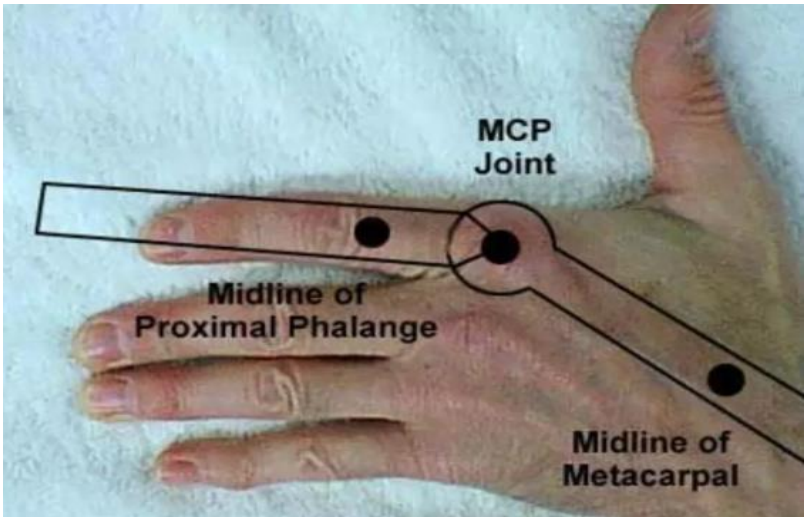

Fig 3.6: Finger Adduction

Finger Abduction: Spreading the fingers apart, away from the hand's midline, or away from the middle finger is known as abduction. The dorsal interossei muscles between the fingers and the abductor digiti minimi muscle on the pinky side of the hand are the main muscles involved in finger abduction. When doing actions that require finger separation, such as grasping a large object, playing musical instruments, or engaging in actions requiring individual finger control, finger abduction is crucial. According to the American Academy of Orthopedic Surgeons, the normal range of finger movements is 25°.

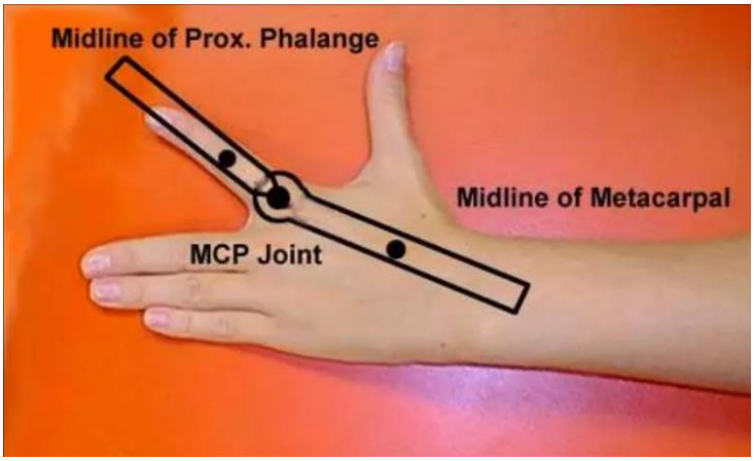

Fig 3.7: Finger Abduction

3.6 GAME DEVELOPMENT

Virtual 3D game creation entails generating engaging and dynamic gaming settings in virtual three dimensions. The following are the primary processes and elements in the creation of virtual 3D games:

Design and Concept: The first step is to decide on the game's concept and design. The genre, target market, gameplay mechanics, plot, characters, settings, and visual style must all be specified. To describe the organization and aesthetic direction of a game, game designers provide design documents, storyboards, and concept artwork.

3D modeling and asset creation: To bring the game's setting and characters to life, 3D models, textures, animations, and other assets are produced. Using specialized software programs like Blender, Maya, or 3ds Max, artists and modelers may create and animate 3D worlds, characters, and objects. Rigging is done to add skeletal structures for character motions, while texturing is done to add realistic or stylized textures to surfaces.

Environment Design: The creation of intricate and aesthetically pleasing gaming environments is the main goal of level designers. This involves creating the architecture, setting, props, and landscapes. To further the immersive experience, environmental design also takes into account lighting, shadows, particle effects, and other visual improvements.

Game Mechanics and Programming: To implement game mechanics and functionality, game developers utilize game engines like Unity or Unreal Engine and programming languages like C++, C#, or JavaScript. Player controls, physics simulations, AI behaviors, game rules, and

interactions with the 3D world are all included in this. Integration of audio and visual effects is also handled at this stage.

Testing and Debugging: extensive testing and debugging are carried out to find and address any faults, bugs, or performance concerns in the game. Testers for quality assurance (QA) evaluate the game's gameplay mechanics, controls, level layout, and overall experience. Based on this feedback, game developers improve and iterate the game.

3.6.1 GAME ENGINE

A game engine is a software platform or framework that offers programmers the tools, libraries, and functions they need to design and build video games. By providing a variety of functions, such as graphics rendering, managing physics simulations, handling audio, implementing artificial intelligence, managing assets, and providing a scripting or programming environment, it acts as a basis for game development. Some of the popular game engines used are Unity, Unreal Engine, Cry Engine, Godot Engine, Gamemaker Studio, Lumberyard, etc. Game engines provide several benefits for game producers, including the speed, accessibility, and adaptability of the game production process. Using a gaming engine has the following major benefits:

Cross-Platform Compatibility: A lot of game engines allow for cross-platform game development, allowing designers to create games for the PC, consoles, mobile devices, and virtual reality (VR). Game engines frequently take care of the technical aspects of platform-specific optimizations and make it easy for creators to export their games to many systems.

Visual and Audio Capabilities: Game engines offer strong tools and skills for building graphically appealing and engrossing games. They also have great audio capabilities. They provide cutting-edge lighting, special effects, rendering, and animation technologies to produce realistic scenes and high-quality images. Additionally, audio integration is supported by game engines, enabling developers to add sound effects, music, and voiceovers to improve the mood and player experience in games.

Integrated Development Environment (IDE): Game engines frequently offer an integrated development environment (IDE), which consists of visual editors, scripting or programming environments, and debugging tools. The development, maintenance, and organization of game assets, levels, scripts, and game logic are made easier by these tools. Developers may more easily prototype, iterate, and debug their games thanks to the IDE's user-friendly interface.

Community and Support: Game engines often have active and supportive communities of developers, artists, and enthusiasts. These groups offer forums, guides, documentation, and other tools to assist developers in their learning and problem-solving. The collaborative, knowledge-sharing, and accessibility of extra assets, plugins, and extensions produced by other developers are all made possible by the community-driven nature of game engines.

For the selection of a game engine, a survey was conducted among firms to know about the best game engine beginners. From the survey conducted, the Unity game engine is selected as the platform for game development.

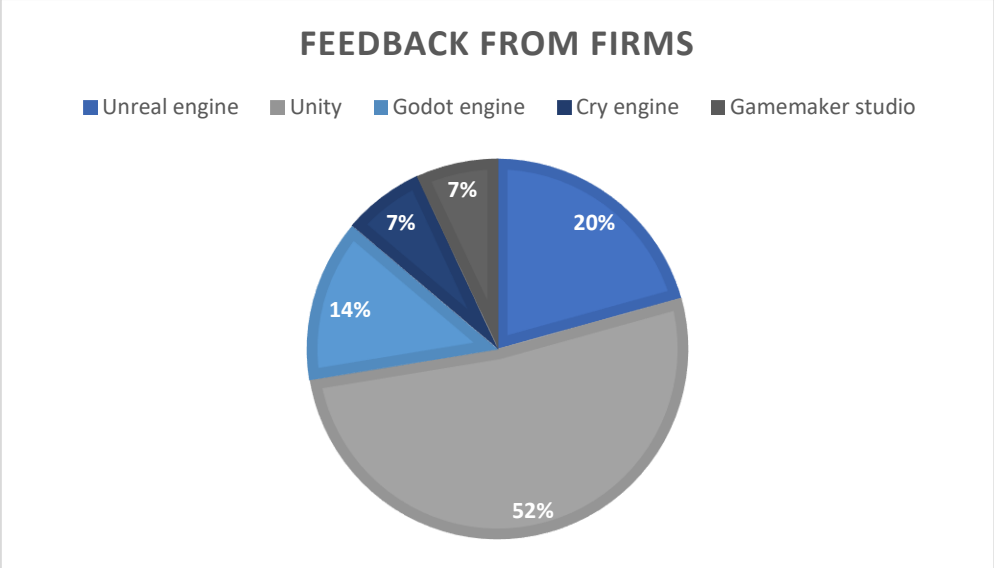

Fig 3.8: Report on the selection of game engine

3.6.1.1 UNITY GAME ENGINE

An extensive selection of tools and capabilities are offered by the well-liked and extensively utilized Unity game engine. Using Unity has several important benefits, which are listed below: Cross-Platform Development: With Unity's support for cross-platform development, game designers can make games for a variety of devices and platforms, including PCs, consoles (such as the PlayStation 3, Xbox One, and Nintendo Switch), mobile phones (such as the iPhone and Android), web browsers, and virtual reality (VR) platforms. By doing this, game producers can reach a larger audience and increase the market for their games.

Visual Editing and Design Tools: Unity offers a user-friendly visual editor that enables programmers to make changes to scenes, levels, and game objects without writing a lot of code. It is simpler to prototype and build game content with the editor's drag-and-drop interface, asset management features, and robust timeline-based animation system.

Scripting with C#: Unity's primary scripting language is C#, which is a programming language. Because of its simplicity and adaptability, C# is popular among programmers of all skill levels. Developers may build bespoke game logic, design interactive behaviors, and include sophisticated systems in their games with the help of C#'s interaction with Unity.

Asset Store: Unity provides a large active Asset Store with a wide selection of pre-built tools, scripts, plugins, and components. To improve their games, developers can access ready-to-use 3D models, textures, sound effects, music, shaders, and other materials. By offering a marketplace for exchanging and gaining access to high-quality assets, the Asset Store promotes community participation and reduces the time and effort required for development.

2D and 3D Game Development: Unity facilitates the creation of both 2D and 3D video games by offering tailored tools and processes for each. For making 2D games, it has a powerful 2D physics engine, sprite animation tools, and tilemap support. Unity provides sophisticated lighting, particle effects, rendering, and physics simulation capabilities for 3D games.

Partnerships and Licensing: Unity provides a range of licensing solutions to meet the requirements of diverse developers. Unity is free to use for personal and small-scale projects, but larger studios and commercial projects may need to purchase expensive licenses with more features and support. Additionally, Unity works with numerous partners and tech companies, giving creators access to extra services, integrations, or tools for certain requirements.

3.6.2 CUBE COLLIDER GAME

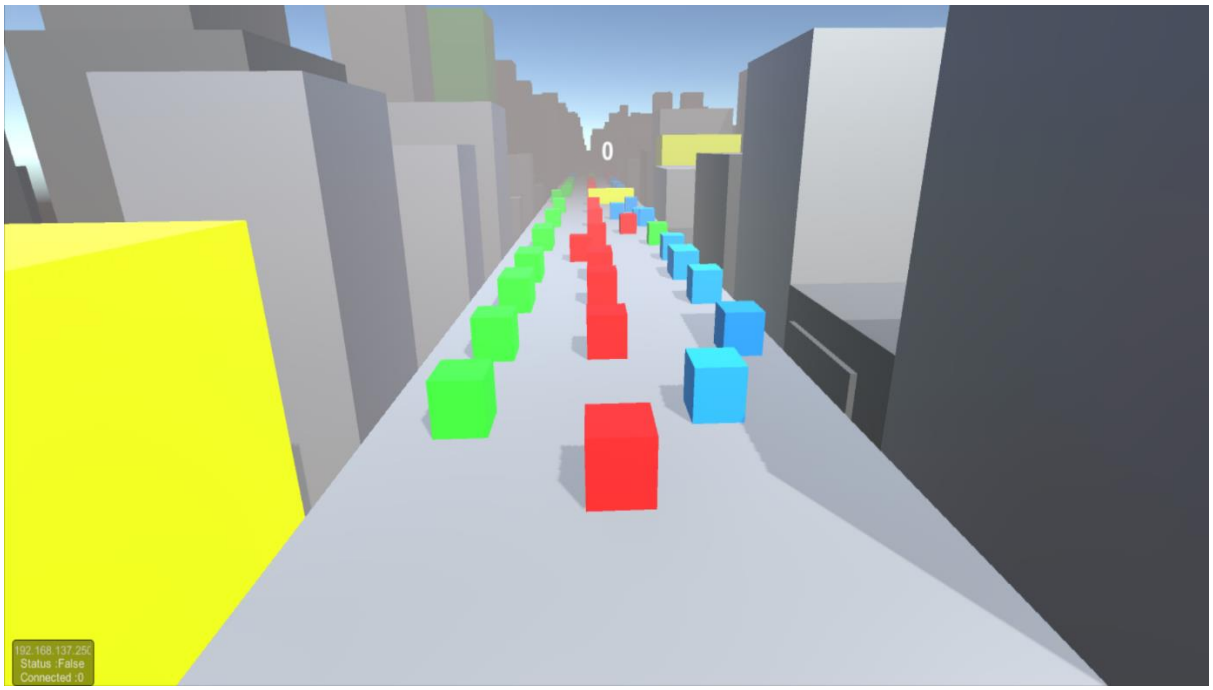

Fig 3.9: Cube collider game

The Cube Collider game tests players' ability to control a cube's movement in a virtual setting in three dimensions. Moving the cube character to gather additional cubes of the same color is the game's goal. The game's operation is described as follows:

Virtual Environment: The game is situated in a 3D virtual environment, on a platform surrounded by a building-like structure. The environment has a variety of barriers and platforms to make the gameplay more challenging.

Character in the Shape of a Cube: The player controls a cube-shaped character, also known as the player cube or the main cube. The cube character is separately controlled by a patient on a smartphone or a tab whereas the game is played on a laptop.

Color-Matching: Other cubes of various colors are dispersed throughout the virtual area. The player's goal is to move the colored cube character and gather colored cubes. If the player's cube is red, for instance, they must explore the game area and collect every red cube there is.

Collision detection: To know when the player cube makes contact with other cubes, the game uses collision detection. When a cube of the same color and the player cube collide, the player cube acquires the other cube, when it comes in contact with another cube of different color the game ends.

Achievements & Scoring: The game may include a scoring system to keep tabs on the player's progress. Points may be provided for each cube gathered, and extra points may be rewarded for beating stages in a certain amount of time or meeting certain goals.

3.6.3 GAME CONTROLLER

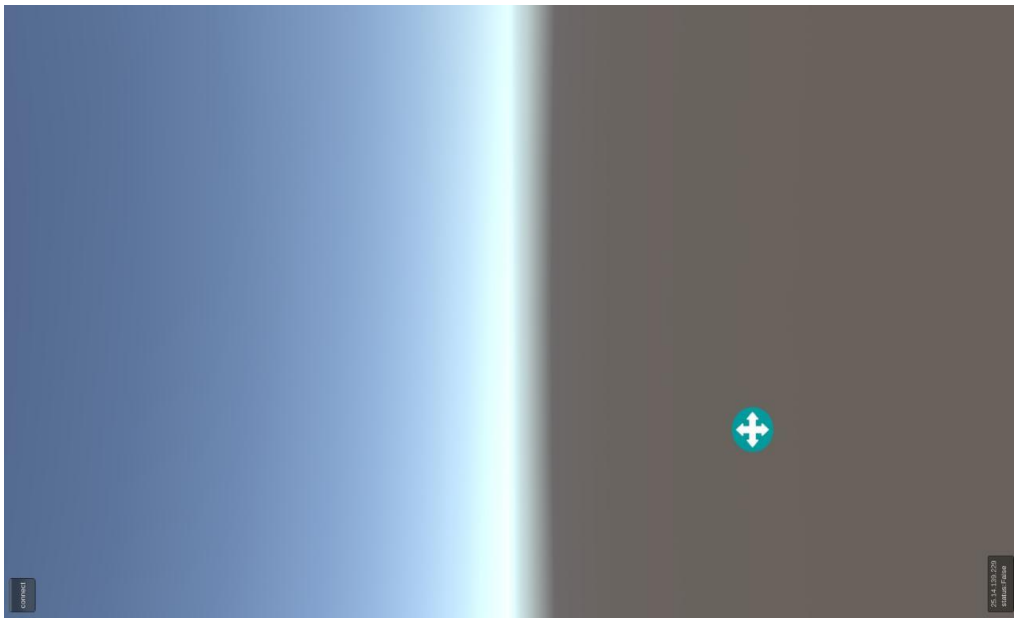

Fig 3.10: Game Controller

The gaming controller is created as a distinct element that must be installed on a smartphone or tablet. The player can control and interact with the game's cube character through this controller window. The controller's operation is described in the following way:

Installation and Setup: The player must download and install the unique controller app or program into their smartphone or tablet to utilize the gaming controller. By using this app, a link is made between the device and the game that is active on the screen.

Controller Window: The player can launch the controller app when it has been installed, and a new window will appear on the device's screen. The controls for controlling the cube character are displayed in this window, which acts as the interface for the game controller.

Controller Buttons: The buttons or virtual controls in the controller window are designed to function like those on a real gamepad or joystick. The player can move the cube character by using these buttons with his fingers, which can take the form of arrows or directional pads.

Controlling the Cube Character: The player can move the game's cube character by interacting with the controller buttons on the screen of their smartphone or tablet. For instance, the player would tap or swipe the matching direction button on the controller window to move the cube character forward. Similarly, moving the cube character in one of those directions would be accomplished by swiping to left, right, or backward.

Responsiveness and Sensitivity: The controller app is made to be sensitive and responsive to the player's touches made on the controller buttons. This guarantees that the cube character responds to the player's input smoothly and precisely.

Integration with the Game: The game software running on the screen is integrated with the controller window and its buttons. The cube character can respond to the player's motions because the game software recognizes the input from the controller window and translates it into equivalent actions in the game world.

The separate input method for controlling the game's cube character is provided by installing the game controller separately on a smartphone or tablet. In comparison to touchscreen controls, it provides a more tactile and physical sensation, resulting in a more immersive and natural gaming experience. Players can easily and precisely manage the cube character by navigating the game world with the help of the controller window, which functions as a virtual joystick on the device's screen.

CHAPTER 4

RESULTS AND DISCUSSION

Fig 4.1: Gaming Architecture

Fig 4.1 shows the designed game architecture, the game is played on a different device, like a laptop or tablet, while the controller is installed on a smartphone that is placed in front of the player. The game device receives the appropriate input signals as the player interacts with the virtual buttons or touch controls on the smartphone controller. These signals are received by the gaming program, which then converts them into the necessary in-game activities like character movement, and object interactions. The images of the game are shown on the game device's screen, giving the player immediate feedback on the game's world and the results of

their decisions. On the larger screen of the gaming device, the player can view the visuals, animations, and other visual components of the game. The player receives audio feedback, including sound effects and background music, through the speakers or audio output of the gaming device. This audio feedback enhances the immersive experience of the game.

To determine whether the gamified application can be used to achieve real-life finger movement. The normal finger ranges are compared with the finger ranges playing the game.

Finger extension:

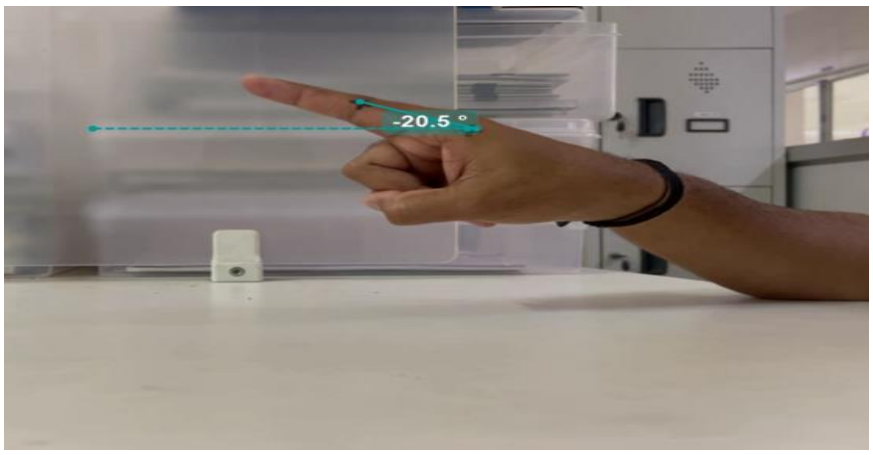

Fig 4.2: Finger extension without game control

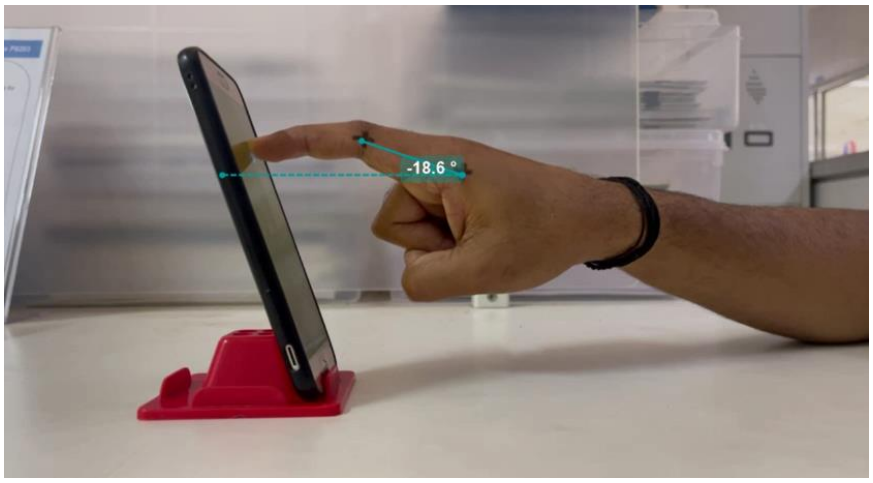

Fig 4.3: Finger extension with game control

From Fig 4.2 the obtained normal range of finger extension is 20.5°and from Fig 4.3 it is known that the angle obtained during finger extension with game control is 18.6°. We can conclude from the comparison of the two that the angle attained during a regular finger extension and a finger extension obtained through game control are almost identical. From Fig 4.3, 4.4, and 4.5 we can understand that when finger extension with the game controller takes place the game object moves to a unit forward.

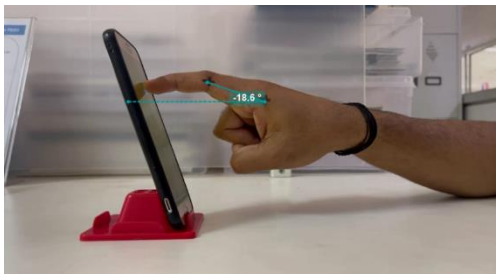

Fig 4.3: Finger extension with game control

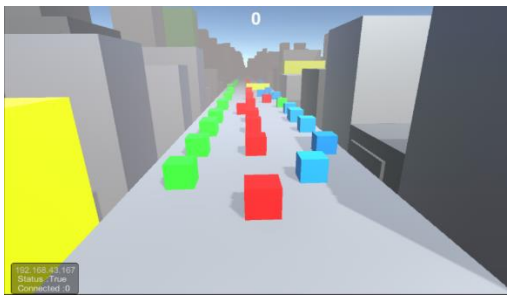

Fig 4.4: Initial game object position

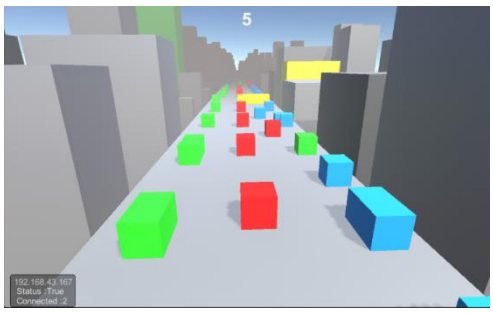

Fig 4.5: Forward- Final game object position

Finger Flexion:

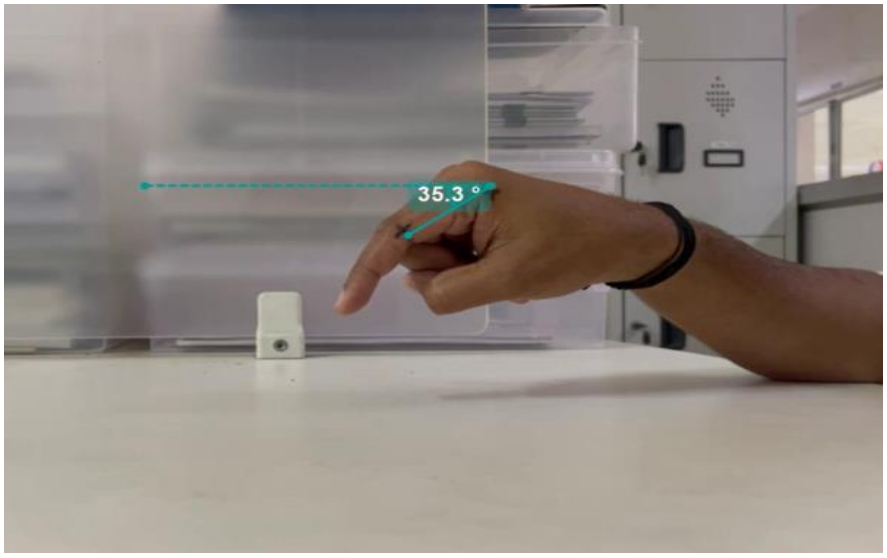

Fig 4.6: Finger flexion without game control

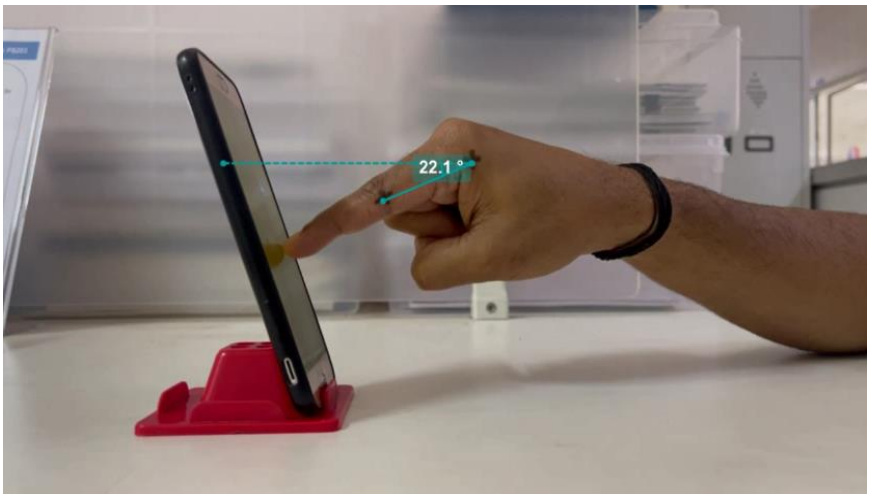

Fig 4.7: Finger flexion game control

From Fig 4.6 the obtained normal range of finger flexion is 35.3°and from Fig 4.7 it is known that the angle obtained during finger flexion with game control is 22.1°. We can conclude from the comparison of the two, that the angle attained during regular finger flexion and finger

flexion obtained through game control are almost identical. From Fig 4.7, 4.4, and 4.9 we can understand that when finger flexion with the game controller takes place the game object moves to a unit backward.

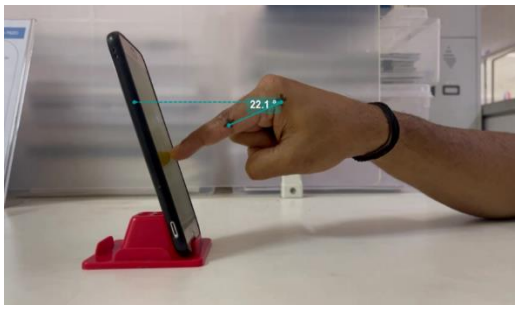

Fig 4.7: Finger flexion game control

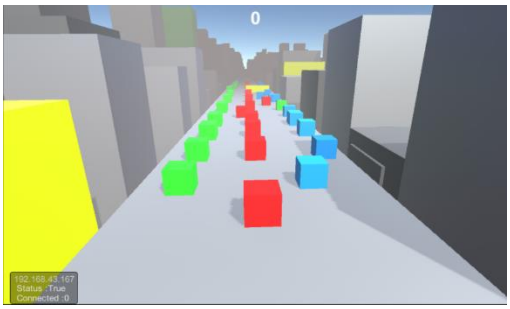

Fig 4.4: Initial game object position

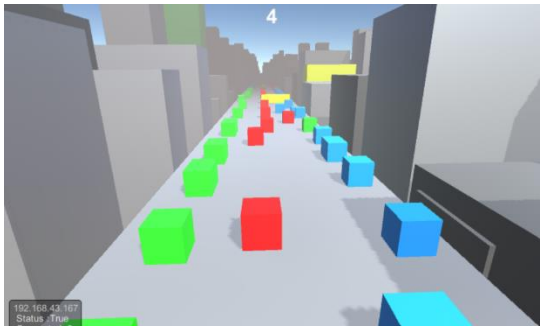

Fig 4.8: Backward- Final game object position

Finger Adduction:

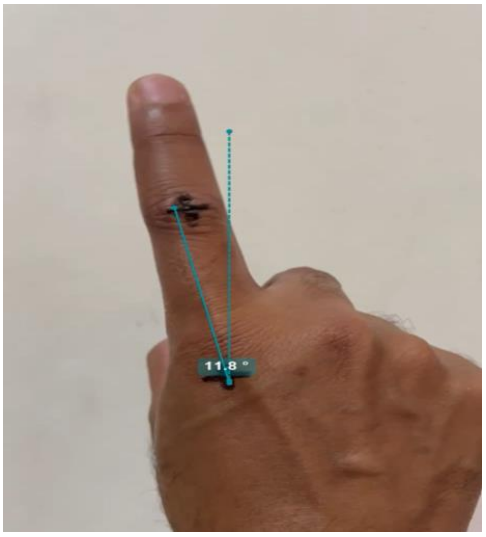

Fig 4.9: Finger Adduction without game control

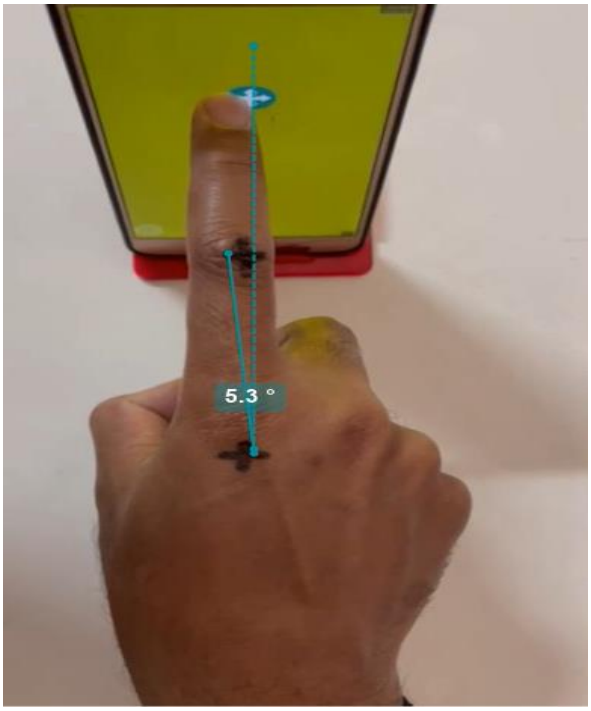

Fig 4.10: Finger Adduction with game control

From Fig 4.9 the obtained normal range of finger adduction is 11.8°and from Fig 4.10 it is known that the angle obtained during finger adduction with game control is 5.3°. We can conclude from the comparison of the two, that the angle attained during regular finger adduction and finger adduction obtained through game control are almost identical. From Fig 4.10, 4.4, and 4.11 we can understand that when finger adduction with the game controller takes place the game object moves to a unit right side.

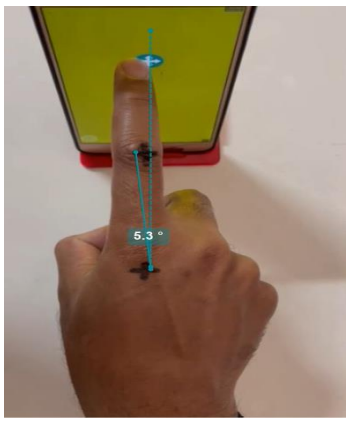

Fig 4.10: Finger Adduction with game control

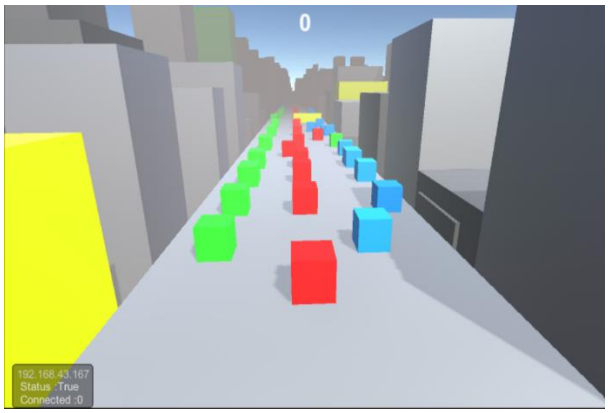

Fig 4.4: Initial game object position

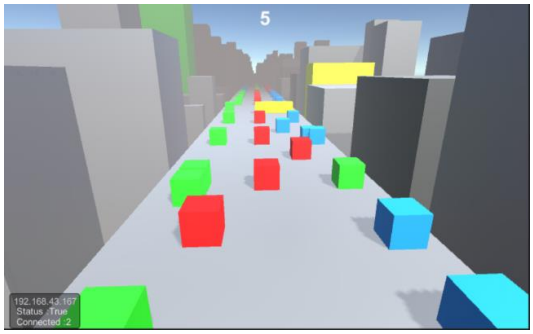

Fig 4.11: Right- Final game object position

Finger Abduction:

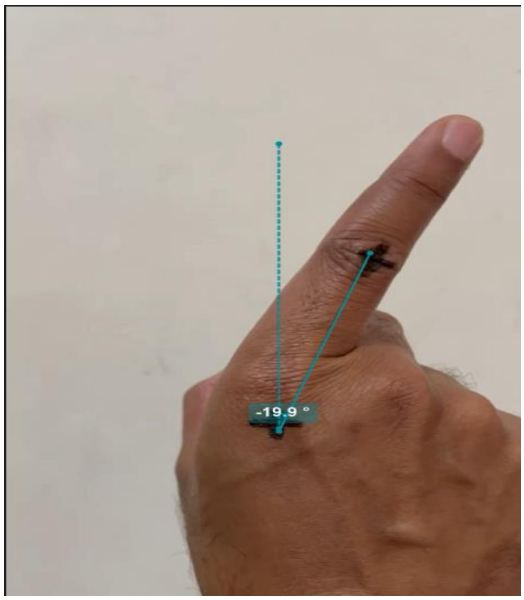

Fig 4.12: Finger Abduction without game control

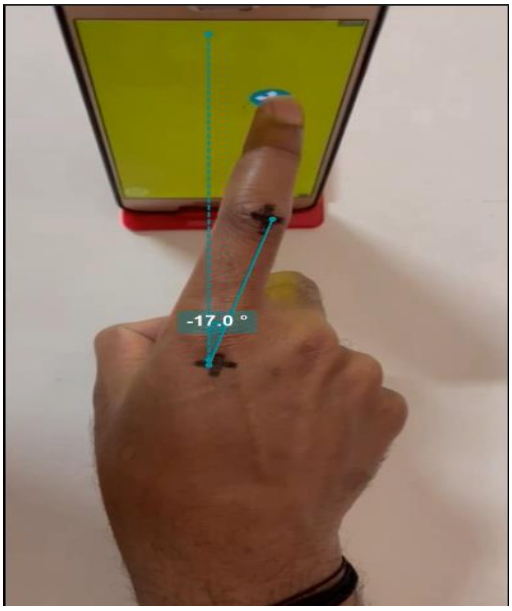

Fig 4.13: Finger Abduction with game control

From Fig 4.12 the obtained normal range of finger abduction is 19.9°and from Fig 4.13 it is known that the angle obtained during finger abduction with game control is 17.0°. We can conclude from the comparison of the two, that the angle attained during regular finger

abduction and finger abduction obtained through game control are almost identical. From Fig 4.13, 4.4, and 4.14 we can understand that when finger abduction with the game controller takes place the game object moves to a unit right side.

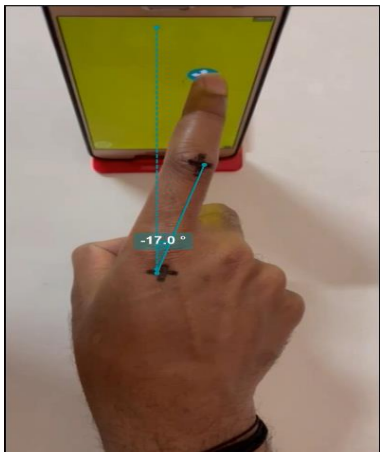

Fig 4.13: Finger Abduction with game control

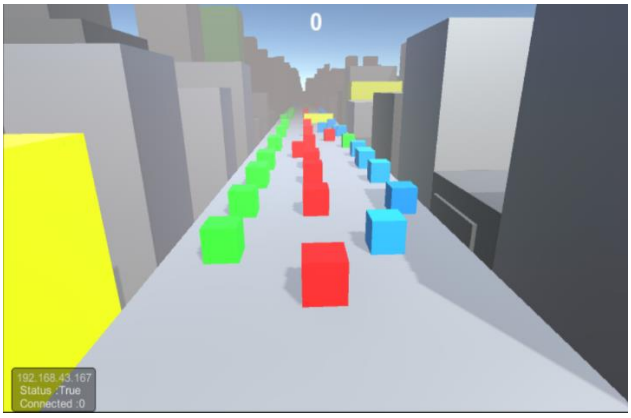

Fig 4.4: Initial game object position

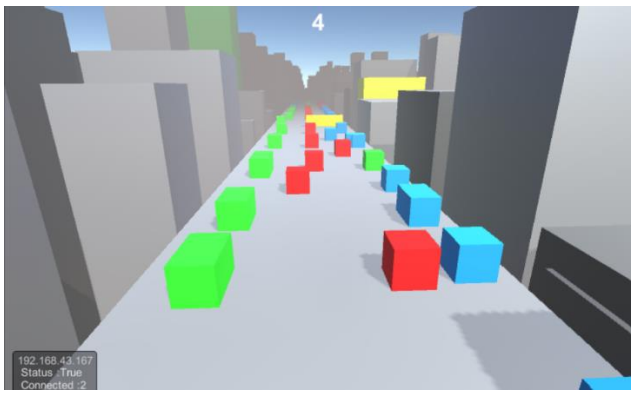

Fig 4.14: Left- Final game object position

The game developed is in such a way that it is for upper extremity hand rehabilitation. A survey was conducted to demonstrate the program developed. From the survey, the physiotherapists suggest that the program developed can be prescribed for stroke patients who come under the 3rd-grade point in the Manual Muscle Power Training, in which patients are comfortable doing initial fine movement coordination. The manual muscle power Training or the ordinal medical research council manual muscle testing scale (MRC Scale) is a scale to evaluate the complaint of weakness, it involves testing a key muscle from the upper or lower extremities against the examiner's resistance and grading the patient's strength on a scale of 0 to 5. coordination (Fine motor control is the coordination of muscles, bones, and nerves to produce small, exact movements). According to the physiotherapists, the game should be played in such a way that the elbow should be arrested or should be fixed on a surface while playing the game. This is because if the shoulder is not arrested, the patient tends to move the stronger muscle rather than the one needed for the rehabilitation. Physiotherapists also suggest that the program is most suited for patients who show early stages of fine movement coordination (Fine motor control is the coordination of muscles, bones, and nerves to produce small, exact movements).

Smartphones, tablets, and PCs are increasingly being used by the general public, the program was created so that it uses the least amount of hardware, which includes a smartphone or tablet and a PC. This makes it relatively easy to implement treatment programs. Due to their portability and small size, these portable gadgets can be used anywhere due to their lightweight design. The movement that we achieve by performing the program is finger extension and flexion, adduction, and abduction.

CHAPTER 5

CONCLUSION

From the above exertion, we can come to the conclusion that gamification can be included in the rehabilitation process. It offers numerous benefits and improves the overall experience for patients by integrating gaming mechanics and aspects into the rehabilitation process. So, by doing this the required movements can be achieved through the gamified application. The program developed can be prescribed for stroke patients who come under the 3rd-grade point in the Manual Muscle Power Training, in which patients are comfortable doing initial fine movement coordination. Gamification improves patient motivation and involvement in rehabilitation. By introducing game elements such as challenges, rewards, and progress tracking, patients are more likely to actively participate and remain committed to their rehabilitation routines. The interactive and immersive nature of gamification creates a sense of enjoyment, transforming mundane exercises into exciting and goal-oriented activities. From the study, it was found that the normal range of motion can be achieved through the gamified application. In conclusion, the introduction of gamification in rehabilitation offers a host of benefits, such as improved social support, higher patient involvement, and significant cost savings. Gamification integration into rehabilitation procedures has enormous potential to revolutionize the industry and improve patient experiences and outcomes as technology develops.

REFERENCES

1. Saeedi S, Ghazisaeedi M, Rezayi S. Applying game-based approaches for physical rehabilitation of poststroke patients: a systematic review. Journal of Healthcare Engineering. 2021;2021.
2. Feigin VL, Forouzanfar MH, Krishnamurthi R, Mensah GA, Connor M, Bennett DA, Moran AE, Sacco RL, Anderson L, Truelsen T, O'Donnell M. Global and regional burden of stroke during 1990–2010: findings from the Global Burden of Disease Study 2010. The lancet. 2014 Jan 18;383(9913):245-55..
3. Langhorne P, Bernhardt J, Kwakkel G. Stroke rehabilitation. The Lancet. 2011 May 14;377(9778):1693-702.
4. Takeuchi N, Izumi SI. Rehabilitation with poststroke motor recovery: a review with a focus on neural plasticity. Stroke research and treatment. 2013 Apr 30;2013.
5. Feigin VL, Stark BA, Johnson CO, Roth GA, Bisignano C, Abady GG, Abbasifard M, Abbasi-Kangevari M, Abd-Allah F, Abedi V, Abualhasan A. Global, regional, and national burden of stroke and its risk factors, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. The Lancet Neurology. 2021 Oct 1;20(10):795-820.
6. Langhorne P, Bernhardt J, Kwakkel G. Stroke rehabilitation. The Lancet. 2011 May 14;377(9778):1693-702.
7. Sisto SA, Forrest GF, Glendinning D. Virtual reality applications for motor rehabilitation after stroke. Topics in stroke rehabilitation. 2002 Jan 1;8(4):11-23.
8. . Baniasadi T, Ayyoubzadeh SM, Mohammadzadeh N. Challenges and practical considerations in applying virtual reality in medical education and treatment. Oman medical journal. 2020 May;35(3):e125.

9. Tuah NM, Ahmedy F, Gani A, Yong LN. A survey on gamification for health rehabilitation care: Applications, opportunities, and open challenges. Information. 2021 Feb 22;12(2):91.
10. nenburg J, Malekian R. Physical activity recognition from smartphone accelerometer data for user context awareness sensing. IEEE Transactions on Systems, Man, and Cybernetics: Systems. 2016 May 23;47(12):3142-9.
11. Choi YH, Ku J, Lim H, Kim YH, Paik NJ. Mobile game-based virtual reality rehabilitation program for upper limb dysfunction after ischemic stroke. Restorative neurology and neuroscience. 2016 Jan 1;34(3):455-63.
12. Grefkes C, Fink GR. Recovery from stroke: current concepts and future perspectives. Neurological research and practice. 2020 Dec;2(1):1-0.
13. Kappen DL, Mirza-Babaei P, Nacke LE. Gamification through the application of motivational affordances for physical activity technology. In Proceedings of the Annual Symposium on Computer-Human Interaction in Play 2017 Oct 15 (pp. 5-18).
14. Sardi L, Idri A, Fernández-Alemán JL. A systematic review of gamification in e-Health. Journal of biomedical informatics. 2017 Jul 1;71:31-48.
15. O'Neil O, Fernandez MM, Herzog J, Beorchia M, Gower V, Gramatica F, Starrost K, Kiwull L. Virtual reality for neurorehabilitation: insights from 3 European clinics. PM&R. 2018 Sep 1;10(9):S198-206
16. Carneiro F, Tavares R, Rodrigues J, Abreu P, Restivo MT. A gamified approach for hand rehabilitation device. International Journal of Online Engineering. 2018 Jan 1;14(1).
17. Janssen J, Verschuren O, Renger WJ, Ermers J, Ketelaar M, Van Ee R. Gamification in physical therapy: More than using games. Pediatric Physical Therapy. 2017 Jan 1;29(1):95-9.