

Understanding User Experiences with ViReG in Children with Cerebral Palsy: A Qualitative Approach

Norazimah Awang^{1*}, Nur Syahela Hussien¹, Suzana Basaruddin¹, Mohd Amin Che Mohd Shabri¹, Masyarah Zulhaida Masmuzidin¹ and, Mazri Yaakob²

¹Universiti Kuala Lumpur, Malaysian Institute of Information Technology, Jalan Sultan Ismail, 50250 Kuala Lumpur, Malaysia

²Universiti Utara Malaysia, 06010 UUM Sintok, Kedah, Sintok, Kedah, Malaysia

* Corresponding author: norazimah.awang@unikl.edu.my

Received: 23 October 2025

Revised: 24 July 2026

Accepted: 9 October 2026

ABSTRACT

Cerebral palsy is the most common neurological disorder that causes children's movement and prevents their daily activities. While this condition cannot be cured, a consistent rehabilitation can improve outcomes. However, traditional rehabilitation treatments are often inaccessible and costly. To address these challenges, virtual rehabilitation gaming (ViReG) technology is strongly recommended to assist children with cerebral palsy to improve their motor tasks. The benefit of this application is its ease of access and usability at any time, in addition to saving costs and time for frequent travel to rehabilitation centers. Virtual reality, a well-established tool in rehabilitation, has been proven effective. Our team has developed a ViReG application for children with cerebral palsy based on the ADDIE (Analysis, Design, Development, Implementation and Evaluation) model. Qualitative testing, including observations and interviews, demonstrated the application's usability and potential benefits. These include enhanced engagement and consistency in therapy sessions. The findings suggest that virtual reality can significantly improve the rehabilitation routines of children with cerebral palsy. Further research is recommended to refine and expand the application, ensuring broader accessibility and effectiveness.

Keywords: Virtual reality, Rehabilitation, Gaming, ADDIE

1 INTRODUCTION

The Malaysian government announced plans in October of 2021 to introduce a healthcare system reform blueprint as part of the Twelfth Malaysia Plan. The goal is to improve healthcare delivery using digital means and to enhance motor tasks for patients with cerebral palsy (CP) such as providing advanced therapies, assistive technologies, and research and development. Virtual Rehabilitation Gaming (ViReG) treatment is an assistive technology that can provide CP patients with therapeutic activities tailored to their specific needs.

A major challenge in the use of ViReG for children with CP is the lack of research dedicated to virtual rehabilitation, particularly for those with complex motor impairments. Examples of studies that focus on virtual rehabilitation for individuals with hemiplegic CP include [1] and [2]. Research by [3] and [4] concentrates solely on finger rehabilitation. Additionally, the repetitive treatments in the health and rehabilitation system can sometimes be inaccessible and costly. For this reason, ViReG technology is strongly recommended for CP patients to help with their motor tasks. The benefit of this application is its ease of access and usability at any time, in addition to saving costs and time for frequent travel to rehabilitation centers.

The study aims to develop and test an interactive ViReG in utilizing innovative technologies and tailored therapeutic activities for children with CP. It is crucial to make rehabilitation easily accessible for children so that they can participate in it regularly without difficulty. This study employs a qualitative research design that incorporates usability testing. The sampling technique involves collecting data from two physiotherapists as expert reviewers and four children with CP as our focus groups, who are involved in CP care for children. The data will be analyzed using field notes. Each of the items captured has been compared among the respondents and appropriate reasoning was produced. The expected outcomes are a new ViReG for special needs with a focus on children with CP. ViReG can empower healthcare providers to create highly personalized treatment strategies for individuals with CP, resulting in significant improvements in their quality of life.

2 BACKGROUND OF STUDY

2.1 Cerebral Palsy

The website of Gabungan Anak-anak Palsi Serebrum (GAPS) reports that CP affects approximately 17 million individuals globally, with one in every 300 children diagnosed with the condition, making it the most common physical disability in childhood [5]. CP is characterized by spastic paralysis and/or other complications, and it is often caused by brain injury during pregnancy or delivery [6]. Diplegia, hemiplegia, and quadriplegia are the three types of spastic CP, affecting the symmetrical parts of the body, one side of the body, and all four limbs, respectively, as shown in Figure 1.

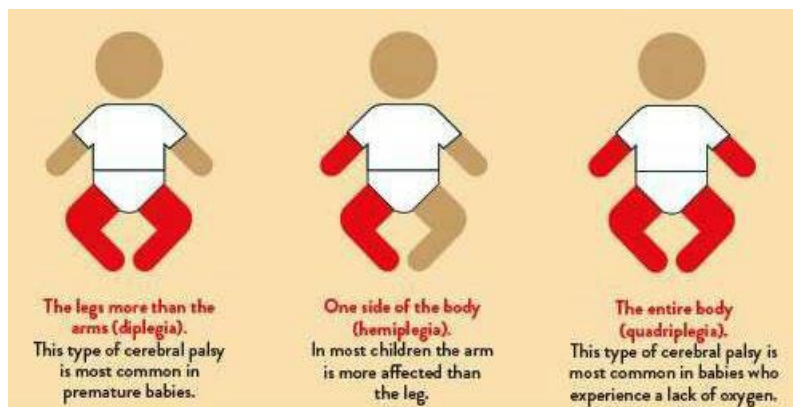


Figure 1 : CP classification

Physical therapy plays a vital role in treating CP in children, as consistent rehabilitation treatment can significantly improve a patient's quality of life and independence, although there is currently no known cure for CP [7]. The primary objective of treatment is to enable patients to achieve their maximum physical and mental potential according to their age and growth, while also promoting their overall well-being. Identifying children with delayed motor development by analyzing typical motor developmental stages and basic reflexes is essential [8]. The primary therapy for CP is vital since the brain and body can develop and change quickly [9]. Parents of children with CP are advised to prioritize early rehabilitation treatment, as delaying treatment until the child's physical condition deteriorates significantly may hinder their recovery and progress towards independence [10].

2.2 Virtual reality

Since the rapid development of virtual reality in the 1990s, it has been applied across various industries. In the field of medicine, for instance, it is used for medical training and education, surgical planning and assistance, patient treatment and rehabilitation, and remote healthcare. These applications of VR in medicine not only enhance the quality of care but also make medical procedures safer and more efficient. By integrating VR into various aspects of healthcare, the medical field can improve training, enhance patient care, and make treatments more effective and accessible. This technology holds great promise for the future of medicine.

One of the most advanced technologies nowadays is ViReG. ViReG is a versatile tool that has been increasingly used in pediatric therapy. Recent studies have examined the effectiveness of gaming consoles and ViReG in rehabilitating children with neurodegenerative disorders and treating neuro-motor diseases [11], [12], [13]. ViReG can also be applied in physiotherapy to evaluate treatment progress, patient performance levels, and muscle stimulus, and collect data for computerized evaluation [6]. This technology provides numerous advantages such as movement analysis, easier evaluation, greater excitement, immersion in a virtual 3D world, and lower cost [9].

2.3 The importance of VR for patient rehabilitation

The study conducted by [1] examined the effectiveness of bimanual upper-limb rehabilitation using VR in young adults with and without hemiplegic CP and found that error augmentation training resulted in greater improvement for participants with CP. [14] reported that ViReG can improve the motor ability, postural control ability, and movement stability of the hemiplegic side in children with CP. [15] investigated user engagement and intrinsic motivation of CP children using video games in a virtual environment and found that lower self-reported motivation was associated with higher performance errors during retention and transfer. However, the study did not provide evidence that the complexity of the audio-visual environment affected children's motor learning or affective state.

Meanwhile, [16] showed that increased engagement during practice can improve motor skills, including speed and accuracy, for both random and repeated tasks, but the study was limited to teenagers at the University of British Columbia and may not be generalizable to other populations. Implementing this framework and its requirements can help design engineers adopt a multi-user approach and modify the design based on stakeholders' goals and preferences. This can ensure a high-quality user experience for both active and potential passive users of smart home devices.

2.4 Scenario of Virtual Rehabilitation Games

Therapy through ViReG has emerged as a popular and effective treatment for children with CP, but the current state of VR games for CP children still has some limitations. A major limitation is that many existing VR games require children to have the ability to understand instructions, which means children with lower cognitive skills may not be able to benefit from them. Therefore, developers should consider creating VR games with simple or one-step instructions for populations with lower cognitive skills.

CP children are classified according to the Gross Motor Function Classification System (GMFCS) into five levels of motor functions as shown in Figure 2. Most VR games that focus on standing balance and gross motor activities are usually usable for children with classification levels 1 and 2, who can stand without support. However, children in CP populations from GMFCS levels 3 to 5 need VR games that can be played while seated. Therefore, developers should create games that meet the demands of wheelchair users, such as games that simulate the propelling or mobility of a wheelchair.

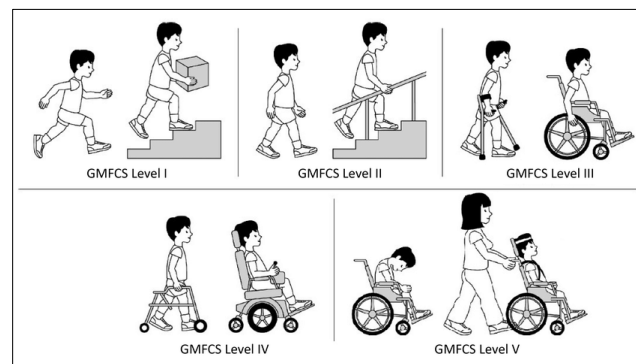


Figure 2 : Level of GMFCS

It would be advantageous if VR games could combine gross motor training, fine motor training, and educational games for advanced users. The use of VR games should follow WHO's recommendations to comprehensively improve an individual's CP body structure impairment, activity limitation, and participation restriction while boosting their motivation and confidence level through appropriate VR therapy. With careful development, VR games have the potential to revolutionize the way therapy is approached for CP children and improve their overall quality of life.

3 METHOD

3.1 The ADDIE Model

The ADDIE model is a fundamental framework in the realm of instructional design and development, providing a systematic and meticulous approach to crafting impactful educational and training programs. ADDIE, which was first used in the 1970s for military training purposes, is an acronym that stands for Analysis, Design, Development, Implementation, and Evaluation. Each of these stages plays a crucial role in developing learning experiences that are both academically sound and customized to satisfy the specific requirements and objectives of the intended audience.

3.1.1 Phase 1: Analysis

In the Analysis phase, the primary focus is on identifying the ViReG criteria based on the specific user interface (UI) requirements for children with CP. This phase involves a thorough review of relevant literature and consultations with experts to gain an in-depth understanding of the necessary UI features for ViReG tailored to the needs of CP children in Malaysia. Five milestones of the study were mapping for 6 months of project development, including identification, design, development, testing, and documentation. Besides, the software Adobe Illustrator will be used for design, Blender will be used for 3D development and Unity 3D will be used for the game.

3.1.2 Phase 2: Design

During the Design phase, a storyboard will be created to visualize the required interface and the instructional process for adopting ViReG. Figure 3 shows the storyboard of the ViReG. This phase ensures that the interface design aligns with the identified criteria and facilitates user engagement. The storyboard starts with the idea that the player wears a VR headset and uses VR controller motion tracking. The player experienced the virtual environment from a first-person perspective, allowing them to see their 3D character within the VR world. In VR the player sees the character like a mirror. The player needs to touch the object by moving their arm or hand.

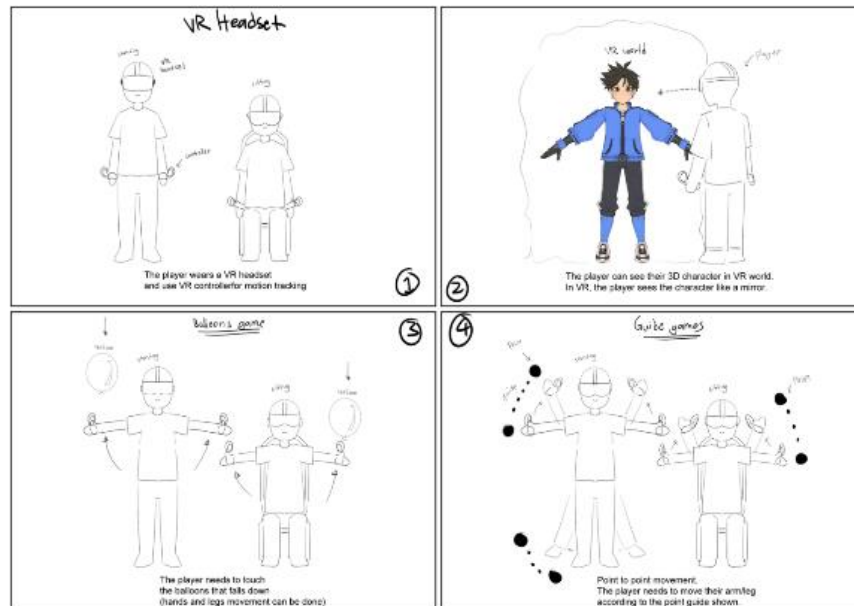


Figure 3 : Storyboard of ViReG

The main part of designing the ViReG is the character design and menu design. The character design specifically focuses on creating two main characters: Amin, represented by a 3D model of a boy, and Myra, represented by a 3D model of a girl. These characters are designed to ensure they are visually appealing and functional within the VR environment. Figure 4 illustrates the detailed design of Amin and Myra from multiple perspectives, including the front, side, and back views. This comprehensive approach ensures that the characters are well-rounded and can interact seamlessly within the virtual world.



Figure 4 : Design of Amin and Myra from front, side and back

The menu design serves as the primary navigation tool in a game, guiding players through different options and functionalities. Consistency in menu design elements, such as button placement and iconography, helps players build familiarity and reduces the learning curve. Games with minimalistic menus often benefit from a clean and straightforward design that emphasizes key functions. Figure 5 shows the start button to play the game for rehab activity.

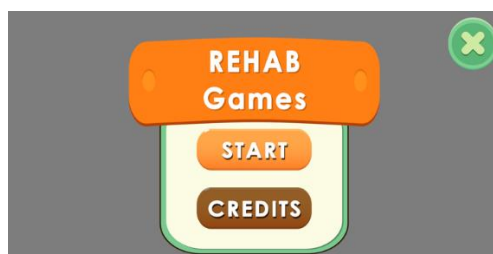


Figure 5 : Main menu

3.1.3 Phase 3: Development

The menu design serves as the primary navigation tool in a game, guiding players through different options and functionalities. Consistency in menu design elements, such as button placement and iconography, helps players build familiarity and reduces the learning curve. Games with minimalistic menus often benefit from a clean and straightforward design that emphasizes key functions. Figure 5 shows the start button to play the game for rehab activity.

In Blender, the developer is tasked with creating a wide range of 3D assets essential for the future virtual environment. This involves designing intricate 3D characters and various objects that will populate the virtual space. Specifically, the assets developed in Blender include characters such as Amin and Myra, detailed 3D stages, and an assortment of fruits designed for specific game scenarios. Additionally, the process of adding bones (rigging) is also carried out in Blender to ensure that the characters and objects can be easily animated and manipulated within the virtual environment. Furthermore, the process of applying textures to characters and objects is also performed in Blender. This step is crucial for adding realistic surface details and enhancing the visual appeal of the 3D models. Figure 6 shows examples of Amin with texture and rigging.



Figure 6 : Amin with simple texture and rigging

After the 3D modelling process is completed, these 3D models will be exported to Unity 3D using the .fbx format. The process of arranging 3D objects and adding lighting to the environment is then carried out. Additionally, knowledge and skills in C# programming are essential to assist with certain processes within Unity. The use of Properties also greatly aids developers in simplifying the game development process. Figure 7 illustrates the environmental development process in Unity. The central window displays a 3D environment with a coordinate axis system, featuring arrows pointing in the direction of the x-axis (red), y-axis (green), and z-axis (blue). These arrows indicate the manipulation handles for moving objects within the 3D space. To the right, there is another window showing a close-up view of an object with similar colored arrows, allowing for detailed adjustments. On the left side of the screen, there is a hierarchical list of objects and settings that are part of the 3D scene, such as 'StageSelector,' 'WorldAxes,' and various camera options. This list helps in organizing and managing different elements within the scene. The interface provides a comprehensive view of the 3D modelling process, showcasing how scenes are constructed and manipulated, which is essential for creating detailed and interactive environments in games or animations.

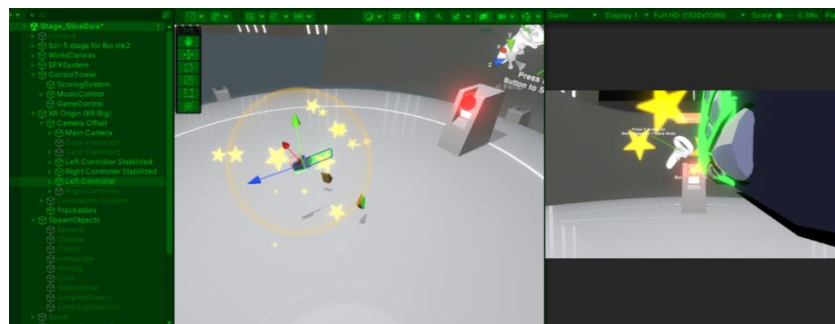


Figure 7 : Slice Play Mode

Figure 8 illustrates the Dance Play mode, where players engage in dance exercises designed to improve their physical coordination and mobility. This mode not only aids in the physical rehabilitation process by enhancing coordination and strength but also keeps players motivated through a gamified and enjoyable experience. The configuration process for the Oculus 2 is also carried out here. This process is done at the initial setup stage to ensure the output meets the desired specifications. If the Oculus settings are configured after the VR development is completed, it can

sometimes cause problems that complicate the developer's work, such as compatibility problems, calibration issues, UI might not fully align, and inconsistent output.



Figure 8 : Dance Play Mode

3.1.4 Phase 3Phase 4: Implementation

In the ADDIE model, the Implementation phase is where the instructional plan is put into action. This phase involves delivering the course material to learners and ensuring that both instructors and learners are prepared. Key aspects include training the instructors, preparing the learners, and organizing the learning environment. For this project, the Implementation phase involved several critical steps. First, therapists and caregivers were trained to ensure they were well-versed in using the game. This training covered understanding the game's objectives, navigating the interface, and assisting children during gameplay. Next, the children were introduced to the game in an engaging and easy-to-understand manner, which included a tutorial session to familiarize them with the controls and objectives. The learning environment was then organized by setting up the necessary equipment, such as computers or tablets, and ensuring the software was installed and functioning correctly. A comfortable and distraction-free space was created for the children to play the game. Finally, a pilot test was conducted with a small group of children to identify any issues and gather feedback, allowing for necessary adjustments before a full-scale rollout.

3.1.5 Phase 5: Evaluation

Finally, this phase involves verifying and validating the application's usability. This phase includes data collection through interviews and observations. A total of four participants were interviewed, including three physiotherapists as expert reviewers and four children with CP participating in a focus group at GAPS. Participants will be selected using purposive sampling to ensure the validity and reliability of the findings. The interviews will be transcribed, and thematic analysis will be employed to identify key themes and patterns. The responses will be categorized meaningfully to align with the research question and techniques such as member checks and peer debriefing will be used to establish validity and reliability. A qualitative approach will be utilized to analyze the data, with field notes comparing recorded items among respondents and providing appropriate reasoning.

In this phase, the researcher will also document the findings and outcomes of the research project. A comprehensive final report will be generated at the end of the research period to ensure that the application development is robust and meets the identified criteria. This report will provide detailed insights into the effectiveness and usability of the ViReG system for upper limb rehabilitation in children with CP, contributing valuable knowledge to the field of virtual rehabilitation. By employing

the ADDIE framework, this research aims to ensure a methodical and iterative approach to the design and development of the ViReG system, ultimately enhancing its effectiveness and usability for children with CP.

4 RESULT

This topic presents an analysis of the testing and evaluation of a ViReG designed specifically for individuals with CP. This testing aimed to assess the effectiveness, usability, and therapeutic potential of the VR game in enhancing motor function and engagement among users with varying levels of CP. The GMFCS was utilized to categorize the participants' motor abilities and tailor the ViReG experience accordingly. This topic will delve into the detailed findings from these testing sessions, offering insights into the participants' experiences, feedback, and the overall effectiveness of the VR game in meeting its therapeutic objectives

4.1 Testing Setting

There are 16 students at GAPS Cyberjaya. 14 of the students are CP students. The explanation has been given to the GAPS president and the president has distributed the consent to all the parents. Finally, only four parents gave consent to be involved in this testing. This testing has been planned to test the students on two VR Games that were developed to assist in the rehab of CP students. The students have been briefed on the session. During the session, the field notes and video recordings will be taken. There are 14 items on the field note, The Oculus Two with controller will be fastened to the respondent. The testing sessions were meticulously organized and conducted on two separate dates: June 20, 2024, and July 22, 2024. These sessions involved participants of different ages and GMFCS levels, ensuring a diverse representation of the CP community. The first session included three respondents, while the second session had one respondent. Each session was held at Tamarind Suites in Cyberjaya, Selangor, and was supported by academic professionals from UNIKL and experienced experts from GAPS.

This testing was conducted on two separate occasions. The first testing session took place on June 20, 2024, from 10:30 pm to 1:30 pm. The Respondent 1 for this session is a female, aged 18, classified as GMFCS Level 4; Respondent 2 is a male, aged 9, also classified as GMFCS Level 4; Respondent 3 is a male, aged 15, classified as GMFCS Level 1. GMFCS is used to classify the severity of motor function in individuals with CP. The second testing session was held on July 22, 2024, from 2:30 pm to 4:00 pm. The sole Respondent 4 for this session is a male, aged 11, classified as GMFCS Level 3. Both testing sessions were conducted at FR-03-03, Tamarind Suites, Persiaran Multimedia, Cyberjaya, 63000 Cyberjaya, Selangor. Three lecturers from UNIKL participated in these sessions: Dr. Norazimah Awang, Dr. Syahela Hussein, and Mohd Amin Che Mod Shabri, along with Dr Suzana Basaruddin. The agenda for these sessions was to test a virtual reality game designed for individuals with CP.

Experts from GAPS also assisted in these sessions. The experts included Rafidah @ Rafizah binti Ahmad, aged 49, who is the President and Founder of GAPS since 2016, and Nurhidayah binti Mat Sarit, an Occupational Therapist with seven years of working experience at GAPS. The involvement of highly qualified individuals from both UNIKL and GAPS provided a robust framework for the testing process. The lecturers from UNIKL brought their academic insights, while the experts from

GAPS, including their President and Founder, contributed their specialized knowledge and practical experience in working with individuals with CP. This collaborative effort aimed to create a comprehensive evaluation of the VR game's potential benefits for CP users.

4.2 Testing

Before the researcher went into analysis, the researcher found it was not appropriate to measure all the data collected statistically due to the ability of respondents varies from each other due different ability of respondents. This can be identified by their level of CP (GMFCS). The higher the level of CP the higher of mini joints (for example the fingers) are not able to work properly. In this testing, there are two respondents in GMFCS Four, one respondent in GMFCS Three and one respondent in GMFCS One.

The VR game testing involved four respondents aged 9 to 18 years, all with varying levels of CP (GMFCS Levels 1 to 4). Respondent 1, who had no prior VR experience and was not a game lover, showed no strong emotions during the game and felt only "just okay" afterwards, experiencing issues with head and hand coordination and dizziness. Respondent 2, a game lover with no prior VR experience, was happy both during and after the game but faced challenges with head strength and small hand size, finding the headset heavy. Respondent 3, with no prior VR experience, felt "OK" before playing and happy afterwards, although they struggled with attention to the left and right movements. Respondent 4, also a game lover with no prior VR experience, was excited before and happy after playing but needed time to adjust to object movements, found the headset heavy, and had difficulty pushing the ball within 2 seconds. Experts suggested various improvements, including adding easier-to-difficult levels, offering movement options, enhancing audio, and tailoring movements to the respondents' abilities.

There are two VR games available for testing: the dance game and the fruit game. For the dance game, the respondent shall select the preferred avatar (choice of girl and boy). Select the song preferred and then click the start button to start playing the game. The respondent shall see a ball and he/she shall move his/her ball in the hands towards the ball. The point will be given once the ball overlaps. This will project 1 movement for rehab. This will be repeated for 2 minutes. And, finally, the final point will be captured. All relevant information, such as the time taken, points, and the respondent's emotions and perceptions, has been documented in the field notes. Additionally, video footage has been recorded for future reference. In the fruit game, the respondent will choose a song and click the start button. Then, students will use a digital sword or long knife to slice the fruit. Points will be awarded for each fruit sliced, and this activity will contribute to one movement for rehabilitation. The game will last for two minutes and will be repeated. Once again, all information, including the time taken, points earned, and the respondent's emotions and perceptions, has been recorded in the field notes.

4.3 Data Analysis

In this study, participants aged 9, 11, 15, and 18 were included. Their scores indicated differences in motor abilities based on their GMFCS levels. Respondents with GMFCS Level 1, who have milder cerebral palsy, achieved higher scores, demonstrating better control over the VR devices and gameplay. This suggests that their motor skills, particularly in controlling the device, are superior

compared to those at higher GMFCS levels. The findings also indicate that the severity of cerebral palsy, as noted in the GMFCS level, is related to the performance scores, with lower levels (GMFCS 1) corresponding to higher scores. Interestingly, all respondents were new to VR gaming, and while two were avid gamers, this did not result in significantly higher scores than non-gamers. Regarding the emotional response to playing VR games, two respondents, both game lovers, expressed excitement, likely due to their prior gaming experience. However, this enthusiasm did not necessarily translate into better performance scores in the VR tasks. Table 1 shows the age group versus the score they achieved in completing the given task.

Table 1 : Age group and score achieved				
Respondent	1	2	3	4
Age	18	9	15	11
GMFCS Level	4	3	4	1

	Dancing Game
	Fruit Game

5 DISCUSSION AND CONCLUSION

Most adolescents and adults with cerebral palsy experience a decline in gross motor function before the age of 35 [17]. The effectiveness of conventional therapy and VR rehabilitation has been studied worldwide, although their effects and benefits remain unclear. The development of VR rehabilitation games is an effort to prevent further deterioration as patients enter adulthood [18]. Many clinical studies have explored the benefits of VR rehabilitation in improving patients' abilities, although its effects still require further discussion, as in [19]. Study [20] explains the need for a detailed description of how the intervention is carried out so that its effectiveness can be evaluated more carefully in future studies. Meanwhile, study [18] shows positive effects of VR treatment on patients.

In this context, the present study provides insights into how children with different levels of motor function and gaming experience interact with VR rehabilitation games. Respondents with GMFCS Level 1, indicating a lower severity of CP, achieved higher scores in the VR games and demonstrated better control over the device compared to those with higher GMFCS levels. This suggests that their relatively mild motor impairments allowed for more effective interaction with the VR system. Despite none of the respondents having prior experience with VR games, two of them were identified as game lovers. However, being a game lover did not lead to significantly better performance in the VR tasks, indicating that familiarity with traditional gaming may not directly translate to proficiency in VR gaming. When it comes to their emotional response, half of the respondents, particularly those who were game lovers, expressed excitement about playing VR games. This excitement could be attributed to their previous gaming experiences, although it did not necessarily correlate with higher scores in the VR tasks.

The VR game testing revealed several issues that hindered the respondents' ability to engage effectively with the games. The head-mounted device was particularly heavy, making it difficult for respondents, especially those with GMFCS Level 4, to wear it comfortably throughout the session. Additionally, the controllers posed challenges, requiring precise eye-hand coordination, which was particularly difficult for those with more severe motor impairments. The controllers were also too

large for children's hands, making them hard to grip properly, and the presence of multiple buttons for different movements added to the complexity, leading to further difficulties. One respondent even experienced dizziness while using the VR headset.

Despite these challenges, most respondents reported feeling happy after playing the VR games, except Respondent 1, who was not a game enthusiast. The feedback, especially from those with GMFCS Level 4, highlighted difficulties in handling the head-mounted device due to physical limitations, particularly in the neck and fingers. Experts recommended increasing the game's flexibility to better accommodate the varying abilities of the respondents. They suggested incorporating a wider range of movements, such as cross-sectional actions, and allowing for customisation of time settings to better align with the individual capabilities of the players.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to the Dana Penyelidikan dan Inovasi MARA (DPIM) (Grant code: MARA.600 – 6/4/3 Jilid 2 (68)) for their generous sponsorship over the past eight months. I would also like to extend my heartfelt thanks to Universiti Kuala Lumpur (UniKL), my workplace, for providing the necessary resources and a conducive environment for this research.

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