PocketRehabv3 Plus: Gamified Android-Based Physical Rehabilitation Monitoring System with Bluetooth Wearable Sensors

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Abstract **-----Recognizing the prevalent issue of patient disengagement due to repetitive rehabilitation routines, gamification was identified as a potential solution to enhance engagement during rehabilitation sessions. This study aims to gamify telerehabilitation and develop an innovative physical rehabilitation monitoring system equipped with Bluetooth wearable sensors to introduce an engaging element into the treatment process. By integrating game elements such as rewards, challenges, and progress monitoring into telerehabilitation, patients can experience heightened involvement in their rehabilitation programs, fostering increased motivation, adherence, and ultimately, improved outcomes. The study marks the third version of the PocketRehab project, aiming to enhance the overall rehabilitation experience by addressing issues of monotony and lack of engagement through the integration of gamified elements into the mobile application. Through the development of a Gamified Android-based Physical Rehabilitation Monitoring System with Bluetooth Wearable Sensors and evaluation of patient engagement levels compared to non-gamified telerehabilitation systems, this research seeks to contribute to the advancement of effective and engaging telerehabilitation solutions.**

Keywords**------Telerehabilitation, Android-based, Bluetooth wearable sensor, Engagement, Gamification**

I. INTRODUCTION

In response to the challenges posed by referral systems in clinics and the obstacles faced in face-to-face physical rehabilitation, particularly exacerbated by events such as the recent COVID-19 pandemic, the development of PocketRehab Versions 1 and 2 was initiated. These versions constitute a monitoring system employing wireless wearable devices, designed to assist patients and aid physical therapists in obtaining accurate angle estimations on patients' limbs.

Despite the advancements brought about by telerehabilitation in the field of physical therapy, insights gleaned from an interview with licensed physical therapist Andrew Gabriel Poa, PTRP, revealed a prevalent issue with patient engagement. Patients undergoing physical rehabilitation often experience boredom due to the repetitive and monotonous nature of their routines. Recognizing this challenge, the integration of gamification was identified as a potential solution to enhance patient engagement during rehabilitation session [1]. In this research, the proponents emphasized the benefits of an IMUbased joint axes estimation method that enables the determination of joint angles without requiring specific IMU-to-segment alignment or calibration motions. They presented a novel approach for estimating the joint axes of the hip and knee joints, which takes advantage of the periodicity observed during gait. Notably, their method is designed to estimate the joint axes of joints with three degrees of freedom (3-DoF). [1]

The proponent of this study proposes a novel wearable gait monitoring system that addresses the limitations of traditional gait assessment methods. The study's objective is to enhance objective gait monitoring in clinical rehabilitation using wearable sensor technology. The force-sensing resistors (FSRs) and inertial measurement units (IMUs) used in the proposed wearable system are attached to a shoe cover. The significance of quantitative gait monitoring, the potential of wearable devices, and the need for additional study to validate and improve the current method for clinical applications are all emphasized in this paper. [2]

The study aims to: (1) develop a Gamified Android-based Physical Rehabilitation Monitoring System with Bluetooth

Wearable Sensors; (2) evaluate the patient's engagement levels using the gamified telerehabilitation system in comparison to the patients who used the non-gamified telerehabilitation system.

II. METHODOLOGY

The proponents conducted testing that consisted of 20 participants who had minor mobility issues. The selected participants conducted the exercises across 1-5 difficulty levels with 30 repetitions per trial. Multiple trials per level were done to ensure accurate data collection. Additionally, we administered a Likert scale survey with 22 questions to each participant to measure their engagement level. Furthermore, we tracked their progress throughout their sessions, recording metrics such as completion time, accuracy, and any signs of fatigue or discomfort. This multi-faceted approach allowed for a comprehensive analysis of both the physical performance and subjective experience of the participants.

Question	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
1. Completing the gamified routine was fun.					
2. I felt excited while doing the gamified routine.					
3. I never felt bored during the gamified routine.					
4. I look forward to doing the gamified routine again.					
5. Completing the routine felt rewarding due to the gamified elements.					
6. The gamified features made me forget I was doing a rehabilitation session.					
7. I felt motivated to get as many points as possible.					
8. I was able to understand and follow the instructions within the program easily.					
9. The game I was playing felt proper to the exercise I was doing.					
10. The game visuals are attractive.					
11. The background music while doing the routine creates a relaxing atmosphere.					
12. The sound cues for each repetition provided helpful auditory feedback during the gamified routine.					
13. The mobile application is easy to use.					
14. The mobile application helped me effectively track my progress and improvements over time.					
15. I am excited to spend my coins on the shop.					
16. I would love to collect more coins.					
17. The achievements encourage me to continue my rehabilitation					
18. I find myself actively wanting to engage in the gamified rehabilitation					
19. The variety of gamified routines offered kept me interested					
20. The gamified rehabilitation enhanced my satisfaction with the rehabilitation process					
21. The gamified elements within the routine encouraged me to push myself further in my exercises.					
22. I would recommend the gamified rehabilitation system to others based on my experience.					

Figure 1. *Engagement Survey Form*

A. Design of the Device

Figure 2 and 3 shows the proposed designs of the chassis.

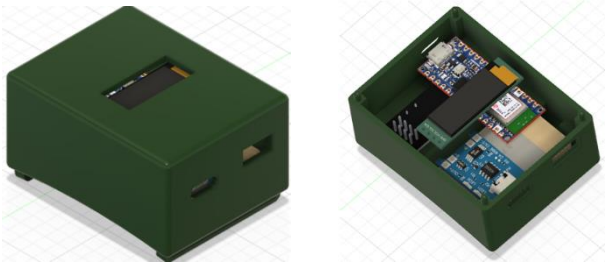


Figure 2 *Chassis Design for PocketRehab Version 3*

Figure 3 *Actual Chassis Design*

The figure illustrates the measured dimensions of the chassis. The dimensions are as follows: Length = 67 mm, Width = 55 mm, and Height = 30 mm. The chassis design incorporates specific holes to facilitate access to the switch, two ports, and an LCD display. The SPDT switch, located on the exterior of the chassis, can be toggled on or off. Additionally, there are two ports situated outside the casing, a Type-C charging port for device recharging and a Type-A USB port for programming purposes. An LCD display is also positioned on the side of the chassis, providing additional visual indications to guide users during their sessions.

B. Design of the Application

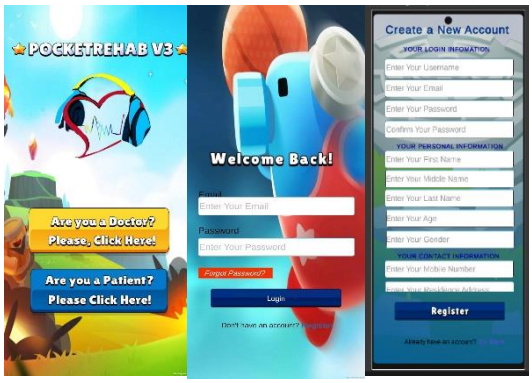


Figure 4 *PocketRehabV3 Log-in and Registration UI*

Figure 4 illustrates the user interface design for the login and registration process, providing a seamless experience for both new and existing users. The login section contains input fields for existing users to enter their username and password, along with a "Login" button to submit credentials

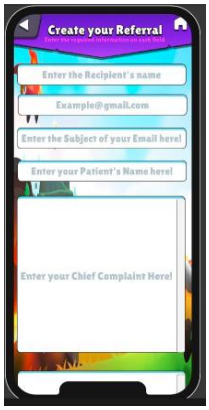


Figure 5 *PocketRehabV3 Referral System UI*

Figure 5 is available in the doctor's user interface, allows physicians/therapists to recommend their patients to other physical rehabilitation practitioners.

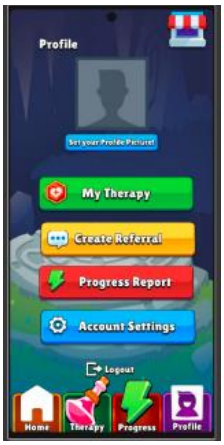


Figure 6 *PocketRehabV3 Profile Page*

Figure 6 showcases the patient's and doctor's profiles within their respective user interfaces.

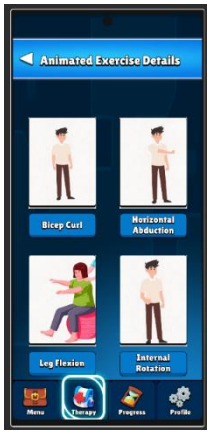


Figure 7 *PocketRehabV3 Exercise List Page*

Figure 7 presents five exercises for the patient to choose from, mainly being Bicep Curl, Horizontal Abduction, Leg Flexion, Internal Rotation, and Shoulder Flexion.

Figure 8 *PocketRehabV3 JMP! Game*

Figure 9 *PocketRehabV3 Hoops Game*

Figure 10 *PocketRehabV3 Sky Defender Game*

Figure 11 *PocketRehabV3 Zen Warrior Game*

Figure 12 *PocketRehabV3 Catch & Mole Game*

Figures 8-12 above show the design of the games integrated into the mobile application. The characters in these games are controlled by sensors that track the movements of five specific exercises. Each game corresponds to a particular rehabilitation exercise.

C. System Flow

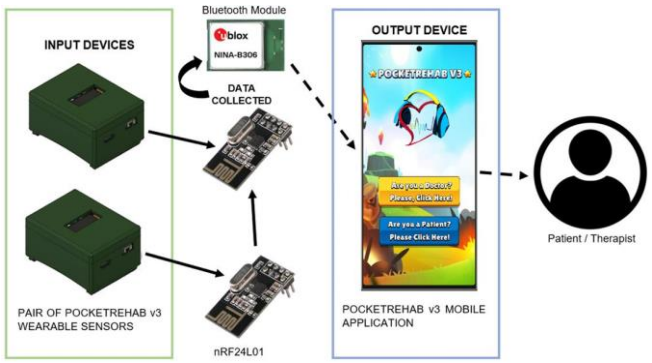


Figure 13 *Physical Rehabilitation*

Figure 13 shows the system of the project. In the physical rehabilitation system, the wearable device should be connected to the mobile application and to be attached to the patient's body to detect the movements of the patient. The data will be then transmitted to the android application. Patients, physicians and therapists can access it by simply logging in to their accounts or signing in. The data will be saved to the cloud storage where the physician can now perform the referral method. In the referral system, the physician can view the records of the patient and decide on choosing the best doctor and is also the only one allowed to do the said method.

D. Functionality

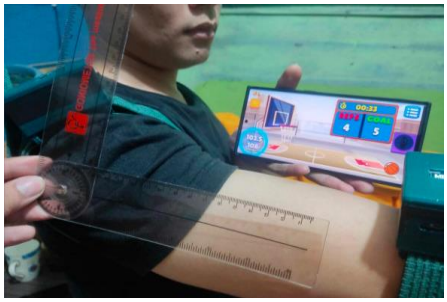


Figure 14 *Testing of Device and Application*

Figure 14 shows the patient wearing the PocketRehabV3 attched to the arms and shoulders while performing an exercise. Before performing such exercises, the patient must connect application to the wearable device using Bluetooth. After pairing of devices, patient must select the appropriate details, such as type of exercises with their designed games, level, and number of repetitions. The device sends information needed to determine the angles and the number of repetitions done for each exercise. The results collected from the device can be seen using the application. Patients can see whether they have achieved 100% and the number of successes for each exercise. When daily activity has been performed, the results can be viewed by the physician using the same applications.

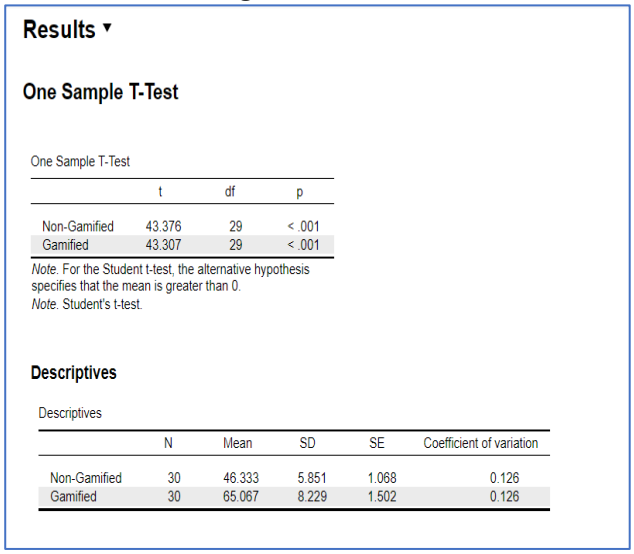
III. RESULTS

Both the gamified and non-gamified surveys are in the format of a 5-point Likert scale system which consists of 15 valid questions each. This makes 75 the highest possible score in both surveys. By multiplying the answer choices to 15, the interpretation for total points has been classified as seen in Table 15.

Table 15: SURVEY SCORE INTERPRETATION

TOTAL SCORE	EQUIVALENT INTERPRETATION
15 - 29	Strongly Disagree
30 - 44	Disagree
45-59	Neutral
60-74	Agree
75	Strongly Agree

Figure 15: *Results*



Results

One Sample T-Test

One Sample T-Test

	t	df	p
Non-Gamified	43.376	29	< .001
Gamified	43.307	29	< .001

Note. For the Student t-test, the alternative hypothesis specifies that the mean is greater than 0.
Note. Student's t-test.

Descriptives

Descriptives

	N	Mean	SD	SE	Coefficient of variation
Non-Gamified	30	46.333	5.851	1.068	0.126
Gamified	30	65.067	8.229	1.502	0.126

Based on the computed data presented in Figure 15, the p-values for both the Non-Gamified and Gamified versions are 0.001, which is below the 0.05 level of significance. This indicates that the null hypothesis is rejected, demonstrating a significant difference in engagement levels between the Gamified and Non-Gamified versions of PocketRehab. Additionally, the total mean for the non-gamified version is 46.333, which corresponds to Neutral, while the total mean for the Gamified version is 65.067, corresponding to Agree. This suggests that patients are more engaged in Gamified rehabilitation compared to non-gamified rehabilitation.

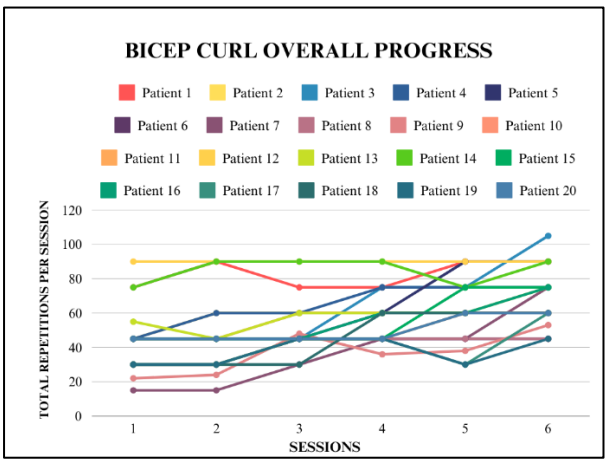


Figure 16: Bicep Curl Overall Progress Results

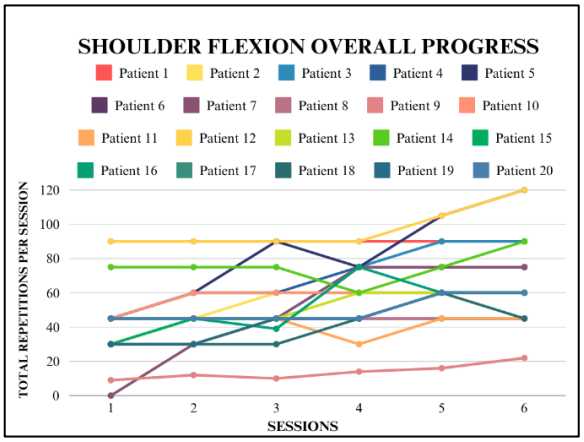


Figure 17: Shoulder Flexion Overall Progress Results

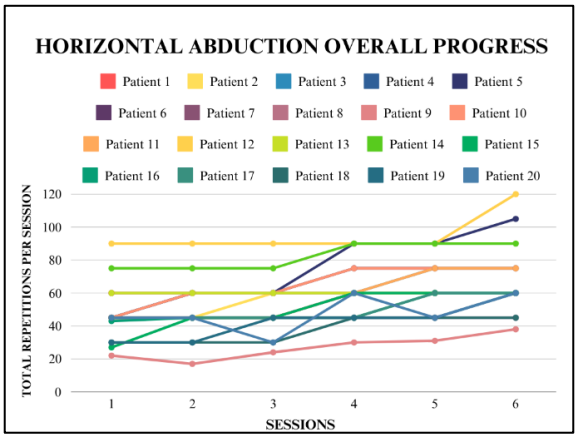


Figure 18: Horizontal Abduction Overall Progress Results

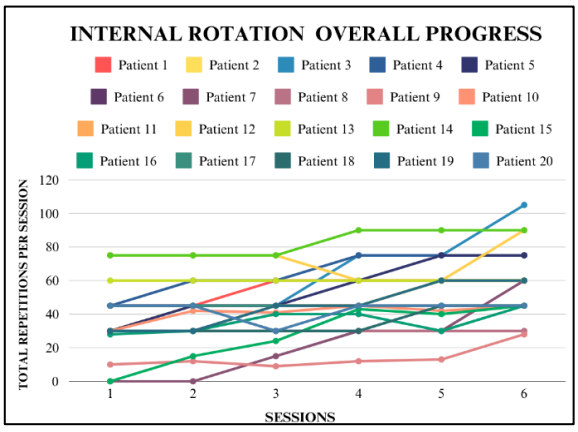


Figure 19: Internal Rotation Overall Progress Results

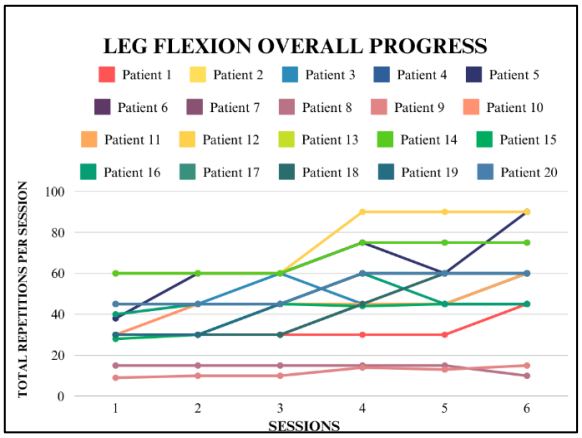


Figure 20: Leg Flexion Overall Progress Results

Based on the figures 16-20, the majority of participants showed sustained engagement and progress in their rehabilitation sessions, with seven patients maintaining consistent repetitions and nine demonstrating continuous improvement, likely due to increased motivation and adherence to the program. Conversely, only a small subset, comprising four patients, exhibited limited progress, which may be influenced by underlying medical conditions. Overall, the results indicate that most patients either maintained or improved their engagement and performance throughout the rehabilitation program.

IV. CONCLUSION

The deployment of the developed system revealed that patients exhibited significantly higher engagement and improved motivation with the gamified version compared to the non-gamified version. Survey results corroborated this, indicating a substantial difference in engagement levels between the two versions. Additionally, patient progress showed a consistent upward trend over six rehabilitation sessions, with the gamified sessions particularly enhancing motivation and engagement across all age groups.

V. RECOMMENDATION

To further enhance the effectiveness and usability of PocketRehab V3, it is recommended to expand the variety of exercises to cover more muscle groups and joint movements, refine existing features while introducing new game types, challenges, and rewards to sustain patient engagement and motivation, and develop iOS-compatible versions to increase accessibility and reach a broader audience, thereby maximizing the impact in telerehabilitation.

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We deeply appreciate the efforts and support from all of you.

VII. REFERENCES

[1] Tuah, N. M., Ahmedy, F., Gani, A., & Yong, L. N. (2021). A Survey on Gamification for Health Rehabilitation Care: Applications, Opportunities, and Open Challenges. Information, 12(2), 91. MDPI AG. Retrieved from http://dx.doi.org/10.3390/info12020091 (accessed Jun 12, 2023)

[2] P. Bitrian, I. Buil, S. Catalan, Journal of Business Research, "Enhancing user engagement: The role of gamification in mobile apps", ScienceDirect https://www.sciencedirect.com/science/article/pii/S0148296321002666 (accessed Jun 12, 2023)