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Article

Evaluation of MyRelief Serious Game for Better Self-Management of Health Behaviour Strategies on Chronic Low-Back Pain

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Abstract: Low back pain is a leading cause of disability worldwide, putting a significant strain on individual sufferers, their families, and the economy as a whole. It has a significant economic impact on the global economy because of the costs associated with healthcare, lost productivity, activity limitation, and work absence. Self-management, education, and adopting healthy lifestyle behaviors, such as increasing physical activity, are all widely recommended treatments. Access to services provided by healthcare professionals who provide these treatments can be limited and costly. This evaluation study focuses on the application of the MyRelief serious game, with the goal of addressing such challenges by providing an accessible, interactive, and fun platform that incorporates self-management, behavior change strategies, and educational information consistent with recommendations for managing low-back pain, based on self-assessment models implemented through ontology-based mechanics. Functional disability measured using the Oswestry Disability Questionnaire showed the statistically significant ($p < 0.001$) improvement in subjects' self-evaluation of their health status. System Usability Scale (SUS) test score of 77.6 also suggests that the MyRelief serious game can potentially influence patient enablement.

Keywords: serious game; self-assessment; lower back pain; behavior change

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1. Introduction

Low back pain (LBP) is a common problem, affecting around one in five people at some time in their life [1], it is prevalent in low, middle and high income countries and has been ranked as one of the leading causes of years lost to disability, according to measured number of healthy life years lost as a result of illness, comparing the relative effect of risk factors [2], as well as tracking public health over time [3]. Healthcare usage and costs associated with LBP vary across countries, however, there is a general consensus that the prevalence of LBP is likely to increase as populations continue to age. Therefore, it is not surprising that there have been calls for increased research efforts to help address the burden of LBP [4]. Accessible and scalable interventions are attractive as these forms of intervention may encourage wider participation and potentially minimise costs associated with other forms of healthcare interventions [5]. Clinical guidelines for the management of LBP consistently recommend that efforts are made to support self-management, to provide education, to encourage resumption of normal activities including return to work and to support engagement in physical activity and exercise. However, the burden of LBP continues to rise and despite increased spending and research in this area, there appear to be no significant improvements in outcomes or prevalence. Clinical guidelines are in place to support consistent best practice [6] and to reduce variation in care that an individual may receive but research suggests that clinical practice is not always in line with clinical guideline recommendations [7]. In recent years there has been an increase in the delivery and development of web-based interventions and in apps supporting self-management of LBP. The effectiveness of such interventions varies [4], but given the scale and costs associated with LBP, interventions that can be individually tailored, provide advice consistent with clinical guidelines that are potentially clinically effective, cost effective and capable of reaching large numbers of people, may be of considerable value. Clinical recommendations regularly urge self-management, which includes components such as greater education, symptom monitoring, and physical exercise, as cost-effective techniques for LBP management, and there is growing interest in the potential use of digital health [8].

Media applications are gradually playing a larger part in the field of physical therapy and psychotherapy as the digital age progresses [9]. While games and apps are still in the early stages of becoming established in the treatment of mental problems, testing with more familiar media such as serious games is still continuing strong. A serious game is one in which the purpose is both teaching [10,11] and behavior modification [12], as well as amusement. Serious games and dedicated apps have been shown to be a successful strategy used to support the self-management of a range of different health procedures [13] and conditions [14] including LBP. In terms of new technology, younger patients preferred visual and dynamic assistance that provided a fun and demanding setting as well as feedback on their performance. Patients who were somewhat older preferred the option of having their workouts coached. Patients expected that whatever tool was provided, they would learn how to use it in a supervised session and have their performance assessed on a regular basis by care professionals; they also expected that adherence would be addressed with them [15].

Gamified approaches have been demonstrated to relieve several types of acute pain, their impact on chronic pain is still in its early stages. Trost et al. [16] emphasize the importance of virtual reality (VR). VR gaming can be used to improve existing chronic pain therapies and examine the potential limitations of traditional VR interfaces in the context of chronic pain, according to researchers who claim that VR gaming can be used to improve existing chronic pain therapies and examine the potential limitations of traditional VR interfaces in the context of chronic pain (CP) [17]. Cryoslide [18], a VR game, was created to test its analgesic impact on chronic pain sufferers, the game's ultimate users, in a clinical setting. Cryoslide considerably decreased felt pain when compared to the baseline and control groups, according to the authors. The findings show that Cryoslide can be utilized as an analgesic intervention for chronic pain treatment in order to reduce pain intensity during symptom spikes. Mbada et al. investigated the usefulness, satisfaction, and gaming experience of a Kinect Xbox controlled non-immersive back extension-glide VR game in patients with moderate severity chronic low-back pain [19]. The RabbitRun game [20] was created to be fun to play and learn, and the majority of participants were willing to play it at home. It was also shown to be capable of improving rehabilitation outcomes because patients with LBP can use the system at home and train for longer periods of time using a smartphone and a low-cost virtual reality device [21]. The recent findings of the study by Stamm et al. also shown a smilar trend that the VR application can reduce the pain intensity [22]. Thirteen people with chronic low back pain (cLBP) and significant pain-related fear participated in the quite recent study [23], which included six VR modules that provided incremental movement exposure across three sessions over a one-week period. The VR application was found to be feasible. Virtual dodgeball was found to be beneficial for increasing lumbar flexion both within and between gameplay sessions, according to Thomas et al. [24]. Participants expressed a very good opinion of the game, as well as no changes in medication use, discomfort, or handicap, as well as no negative side effects.

In contrast to the VR games, there are less research based traditional format games for managing the back pain, but these also continue to exhibit a promising trend. For persons with nonspecific low back pain, digital therapeutic care applications give a new effective and scalable strategy (LBP). Personalized decision-support treatments that enable the user in self-managing LBP are also driving digital therapeutic care applications, which may induce long-term behavior changes to lower the frequency and intensity of pain episodes.

Although serious games show promise, there are still many questions surrounding how these games should be developed, organised, and delivered [25], and as such there is a need for pragmatic evaluations to inform theory around the proposed mechanism by which the game works and the influence it has on patient outcomes. Furthermore, most existing applications require using expensive VR equipment which is often not available at a general household [22,26,27].

The main goal of our research was to investigate interactive approach aimed at improvement of knowledge and skills of working adults regarding evidence based strategies that can help individuals manage their low back pain. Therefore, in line with clinical guidelines, a MyRelief serious game was developed as a smartphone app to support knowledge acquisition regarding self-management strategies, and to support individuals in adopting behaviours that are more consistent with a better prognosis, with different modifiers identified, such as physical factors, psychological factors and socio-environmental factors [28]. This paper describes the content and development of the MyRelief game, and the results of an evaluation study conducted in Lithuania, over the autumn period of year 2020 (original) and 2021 (control).

Paper is structured as follows. Section 2 presents and discuses the challenge model of the MyRelief game, the knowledge transfer model, and describes their implementation as an app. Section 3 presents and describes the results. Section 4 presents discussion, and finally, Section 5 concludes the manuscript.

2. Materials and Methods

2.1. The Challenge Model

This section explains how the challenge model works that enables estimations of a player's capacity and degree of challenge, enabling for the automatic provision of a suitable activity at an appropriate challenge to the players - is presented in this section. The challenge model of the MyRelief game is depicted in Figure 1. The serious game has to balance between the active gameplay (to stay involved) and knowledge transfer leading to a behavior change, through changing of self-assumed concepts, directing self-efficacy, developing physical and psychological capabilities as well as communications and social aspects. Active gameplay challenges the user in 3 main ways: first in modified MYMOP [29] based assessment of self-tracking symptoms and pain related issues. Then, second, physical activity monitoring (either through services like Strava or in-app entered data of physical activity). And most importantly, third, knowledge component, knowledge base of learning materials terraformed into interactive quizzes and handbook materials, in a cooperation with Udemy based MOOC on these issues [30].

The game motives users to continue by offering unlock points of various different characters, combat arenas, and themes enhancing the game experience. Role Model is a hero representing the avatar fighting the monster of pain, which can never be truly defeated, but can be made less scary or even friendly. Performance and feedback are closely related as the game represents a gain in knowledge and in a general pain management through travelling and combating pain monsters within the actual interaction with the user, thus providing enjoyment in learning.

Thus, the challenge model leads to increased coping with back pain by indirectly changing the behaviors of the player: Tracking physical activity might lead to more physical activity and possibly even workouts, better habits of healthy life, and a knowledge transfer model is needed to lead to better psychological handling and activities.

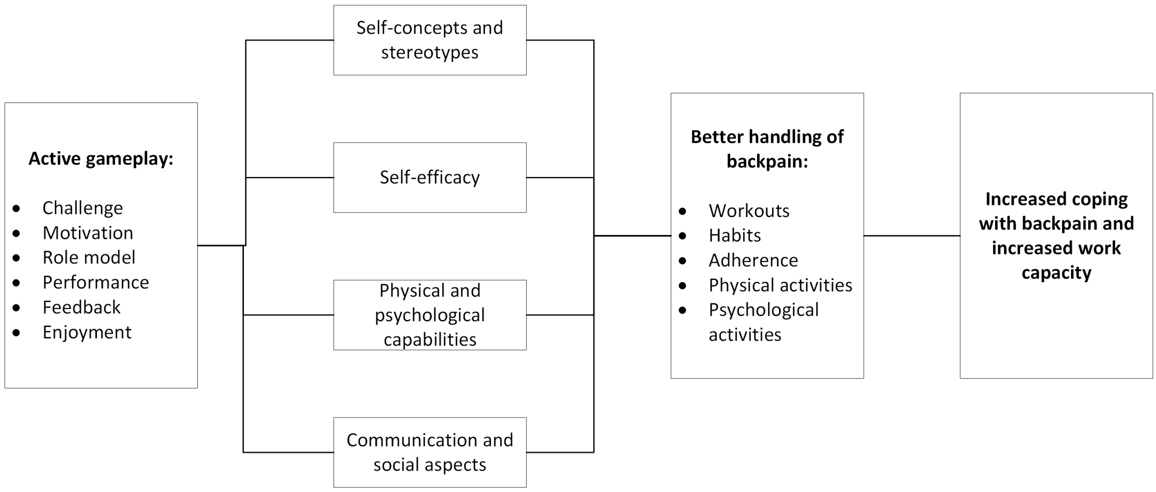

Figure 1. Challenge model of the MyRelief game.

2.2. Knowledge Transfer Model

Knowledge transfer models (KTMs) are commonly used to model knowledge transfer in complex social collaborative processes such as teaching/learning process [31,32] and this section illustrates our adaptation. Figure 2 illustrates a KTM which was developed to boost the player's (typically a mature worker) self-confidence in pain management and complement the knowledge in the MOOC related to back pain management (openly accessible with the game). The game starts in a close relation to MYMOP mechanism [29] to assist the user on setting goals and criteria leading to an advancement in managing the back pain. This KTM has built in knowledge assessment (game performance) evaluation mechanisms, closely related to learning activities, and depending on the user's responses, can be categorized as adequate or insufficient levels of effectiveness in knowledge transfer. The model is designed to track the progress of learning and offer insights through an interactive scoring system.

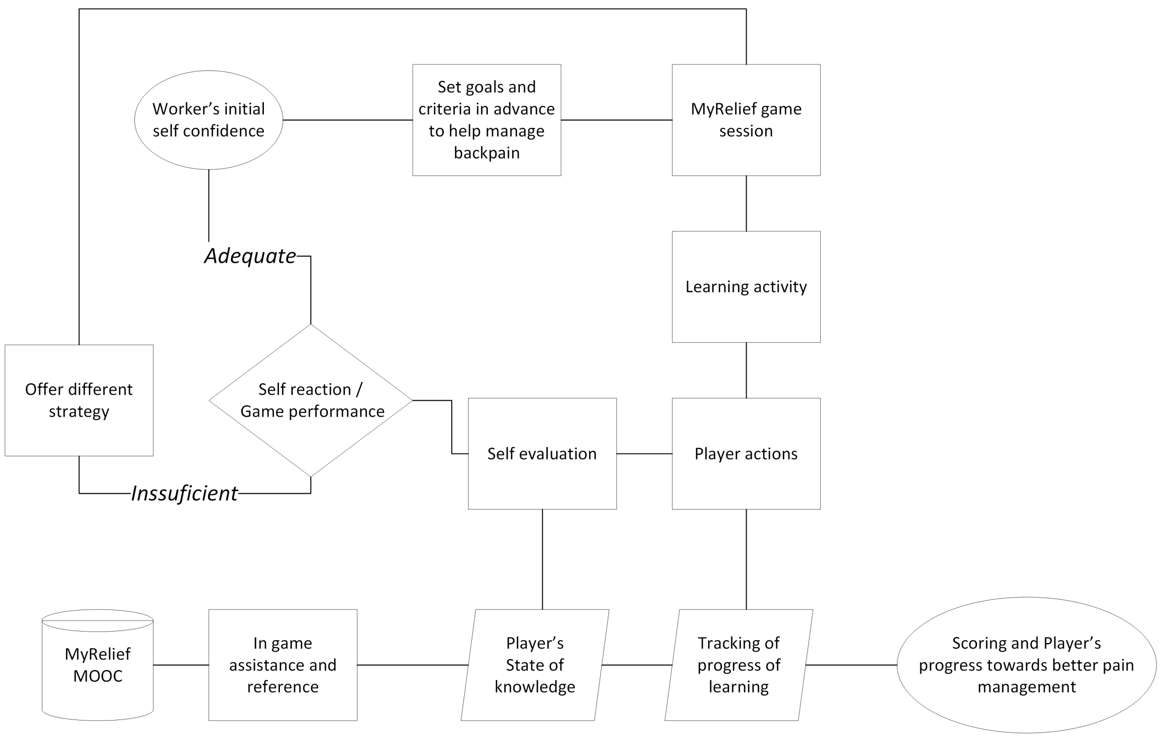

Figure 2. Knowledge transfer model.

2.3. Ontology Based Approach

To address the issue of semantic variety in data sources, this section explains models of representation with defined concepts and stated connections linking them, as we have adopted the ontology based approach for developing educational activities and systems [33]. The mechanics of the game were based on the ontology based scenarios depicted in Figure 3. Each person starts the game by setting his own personal objective - the baseline of pain-related issues as well as general physical activity levels. The game tries to survey the progress in weekly follow-ups as well as daily (or on each run) questionnaire (knowledge-based) mechanisms while combating the pain monster. This interactive assisted self-assessment method can quickly measure up and lead towards developing a healthier lifestyle and higher confidence towards back pain issues. Alternatively, in an inefficient case, the user can reset a progress and try a different path.

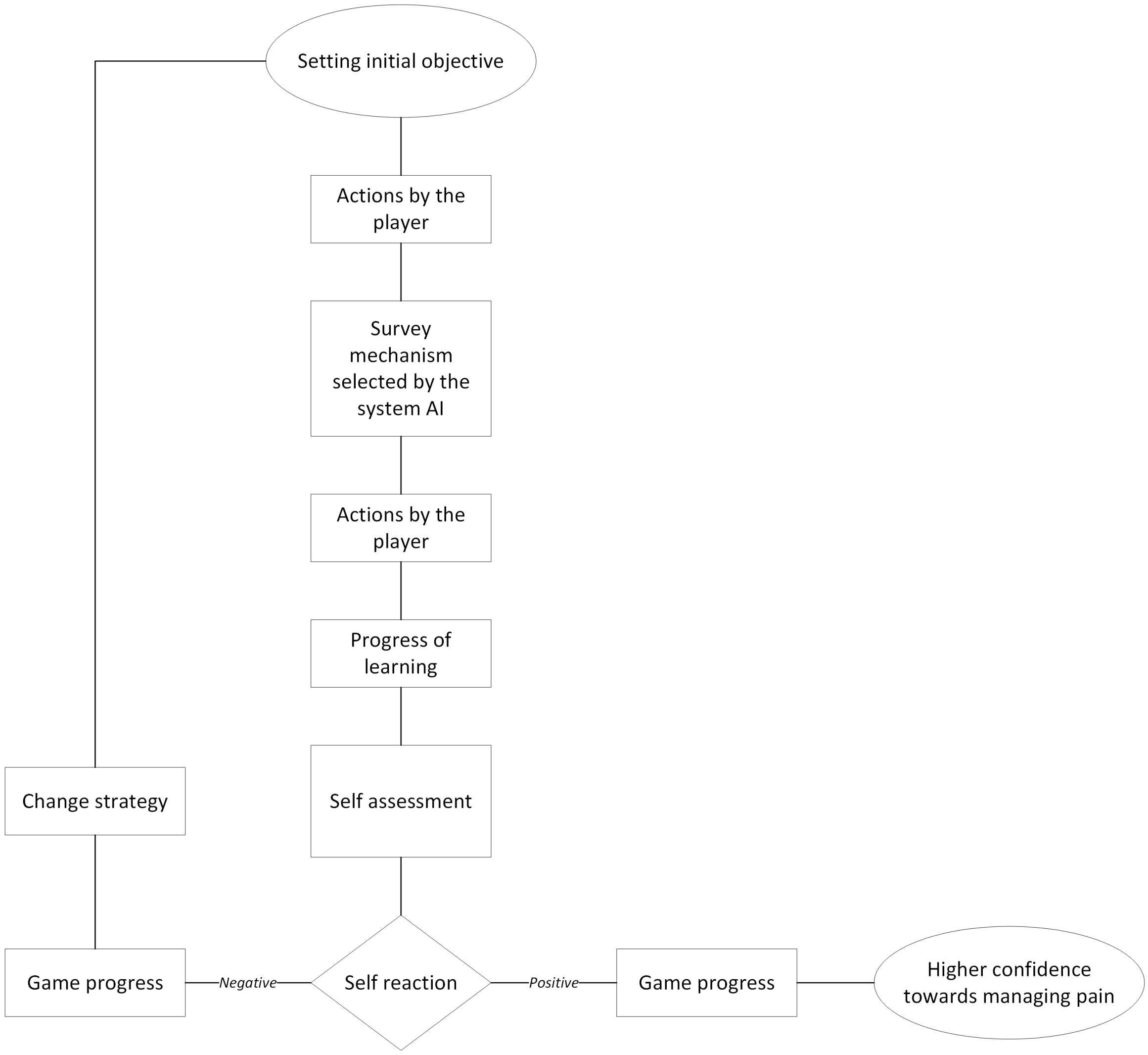

Figure 3. Ontology based scenario driver.

The ontology based approach can be categorized in three different levels. Level 1 depicted in Figure 4 explains the first stage of generalizing the initial knowledge of a learning phase. The app introduces objectives (what our user should be aiming to achieve), self-assessment criteria (what are the mechanisms, later on represented by character interaction as our avatar combats pain), and how will progress be measured (through the increase of scores and a number of pain monsters fought).

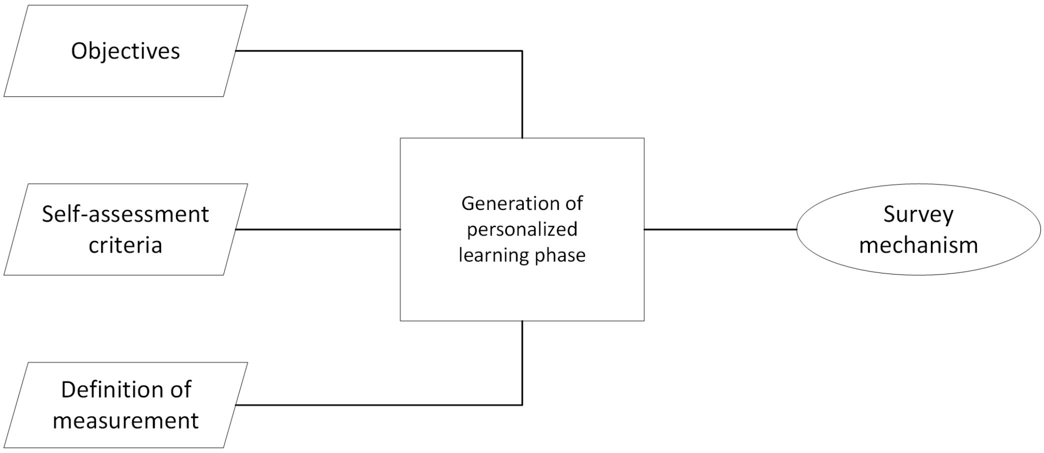

Figure 4. Ontology based approach—level 1.

A second level approach explains a more complex running phase of a learning process. User creates an avatar and starts the flow of self-survey and knowledge assessment (see Figure 5). App allows triggering numerous knowledge assessment scenarios based on the knowledge base offered in MyRelief project's MOOC in the Udemy platform [30]. Feedback is illustrated through successful (or not) combat with pain monsters which represent how efficiently a user was able to solve a given quiz task. In case of an incorrect answer a user might be directed to a brief description of a given topic in builtin handbook or more in depth materials in the mooc and relate it to current handling of back pain (based on MYMOP tracking mechanism) which also influence the game flow.

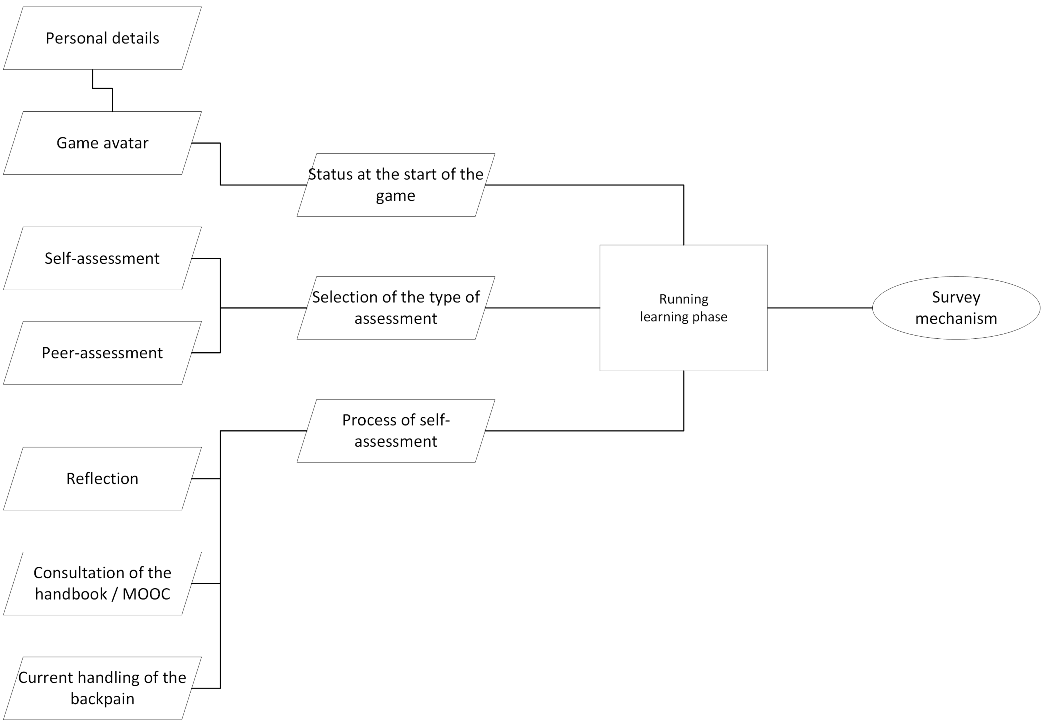

Figure 5. Ontology based approach—level 2.

Third and final stage (see Figure 6) is geared towards assessing the effectiveness of knowledge comprehension. User might be offered to reset his progress or switch to a new series of game quizzes, better assessing his skills in a given set or even in a different topic to attract and keep the user within the game.

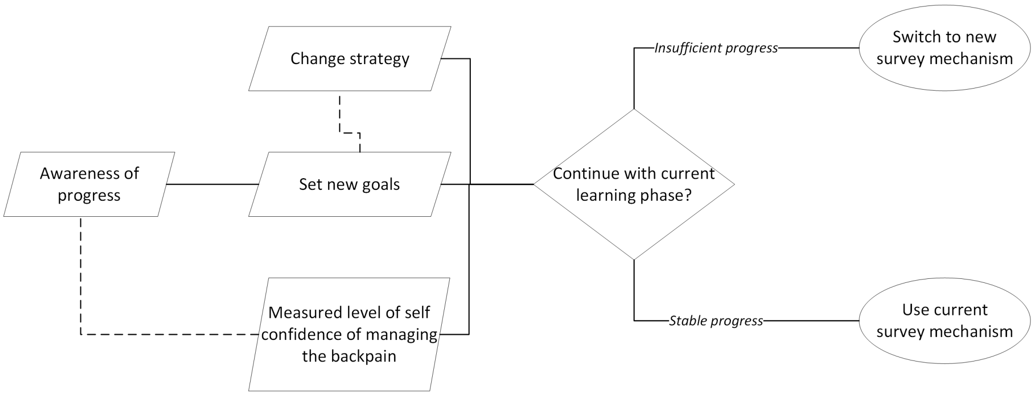

Figure 6. Ontology based approach—level 3.

2.4. Logical Flow of The App

This section explains how the logic of the app was implemented. The implementation of the above ontology based knowledge transfer model is displayed in Figure 7. MyRelief serious game starts the workflow by displaying greeting messages and retrieving step count (from phone data, from online sources such as Strava or manually). This value is one of the common measures of a user's physical activity and depending on the norm or deterioration from norm, it greets, encourages, and motivates our player. Furthermore, an interactive MYMOP based survey is launched to initiate or track user's pain coping progress. In addition, the ontology-based knowledge assessment model is initiated and user knowledge and motivation is survey through generated questions with correct (or not) answers dictating game avatar's performance in combat with pain monsters. Depending on player efficiency different sets of ontologies might be employed as was illustrated in Figures 4–6.

2.5. Evaluation of Functional Disability

Functional disability is measured by the Oswestry Disability Questionnaire (ODI) [34], following the guidelines on the low back pain scenario [35,36]. The ODI is made up of ten components, each with six levels (with a maximum score of five points in each area) that measure a person's limits in various everyday tasks. The total potential score is divided by the sum of all 10 parts, and the result is multiplied by 100 to produce a percentage score. The scale runs from 0 (best health status) to 100 (worst health state), with chronic back pain individuals scoring 43% on average. For an individual patient, a minimum significant shift of 10–12 points over time or a 20–30% improvement from baseline has been advised.

The patient's ability to understand and cope with LBP and life following the use of the Serious game is measured with an adapted version of the Patient Enablement Instrument (PEI) [37], following the guidelines of best practices in back pain [38,39].

2.6. Statistical Analysis

For statistical analysis, the Games-Howell test is used to compare all conceivable combinations of group differences, when the assumption of homogeneity of variances is not supported. This post hoc test calculates confidence intervals for group mean differences and determines if they are statistically significant. The test evaluates the differences between each pair of means, with multiple testing appropriately adjusted. As a result, no more p-value modifications are required.

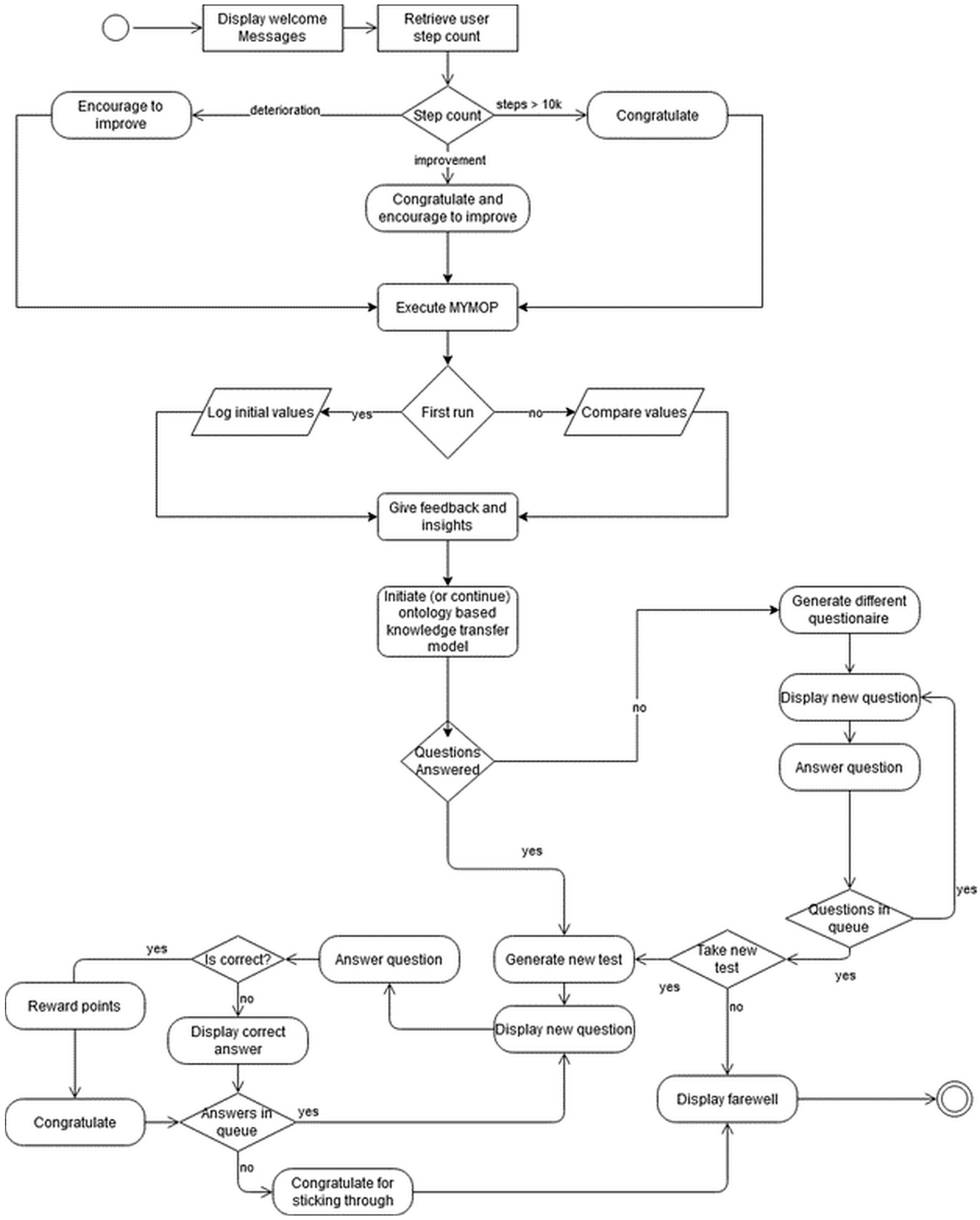

Figure 7. Execution logic of MyRelief serious game.

2.7. Evaluation Of Usability

The usability of the serious game is evaluated with the System Usability Scale (SUS) [40]. SUS is a ten-item scale that provides a global picture of subjective usability judgments. The SUS's selected statements are rated on a five-point Likert scale and include a wide range of factors of system usability, such as the need for help, training, and complexity, and so offer a high level of validity for assessing a system's usability [41]. Participants will provide a score from 1 to 5 to each question based on how much they agree with the statement they are reading. They agree entirely with a score of 5, while they strongly disagree with a score of 1. The 10 questions are asked on the system and the subject's interaction with the system on: Intended frequency of use (Q1), complexity (Q2), ease of use (Q3), the need for assistance (Q4), integration of functionalities (Q5), inconsistencies (Q6), learning curve (Q7), convenience to use (Q8), confidence (Q9), and the need of prior knowledge (Q10).

3. Participants and Results

3.1. Participants

The study included 48 participants recruited in the Grand Office Building (two groups: The first of 21 person, serving as control, and the second of 27 person, playing the game). Participants were surveyed in 2020 and in 2021 (for a total period of three months per year). Age distribution was from 24 to 76 years old (mean 34 years old), 18% identified themselves female, 1% as other, and 71% as male. Non of the participants were payed and people involved participated on a voluntary basis, correlating with the relevance of the problem of back pain.

3.2. Results

The results of ODI are presented in Figure 8. Our results show statistically significant ($p < 0.001$) between game group and control group after the conclusion of the experiment. There was no statistically significant variations between all genders surveyed.

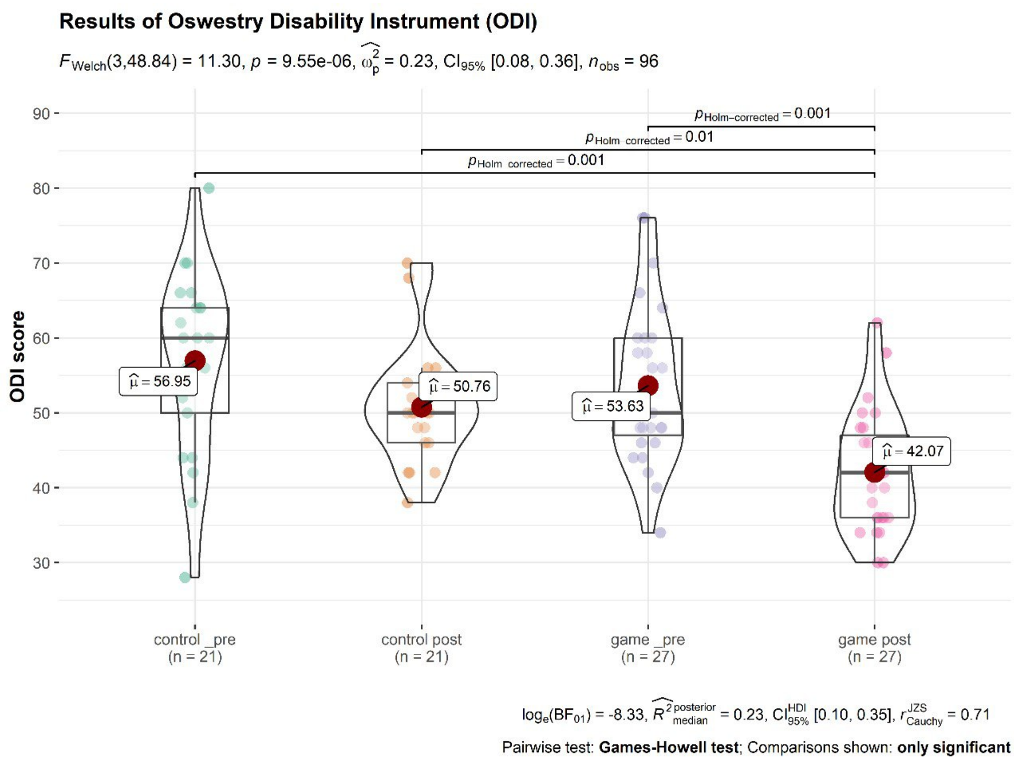

Figure 8. Results of Oswestry Disability Questionnaire (ODI).

The results of PEI are presented in Figure 9. The difference between the game group and the control group was not statistically significant ($p = 0.182$), although the game group achieved better result ($\mu = 5.7$) vs. the control group ($\mu = 4.81$).

The results of SUS are presented in Figure 10. The interpretation of SUS scores follows the following heuristic scheme: >80.3 (excellent), 68–80.3 (good), 51–68 (poor).

The results of SUS evaluation showed poor learning curve ($Q7 = 67.0$) meaning that the game may have been too difficult for subjects to master, perhaps, due to some inconsistencies ($Q4 = 84.0$). On the other hand, the subjects liked the game and wanted to use it frequently ($Q1 = 88.0$) and the interface of the game was convenient ($Q8 = 87.3$).

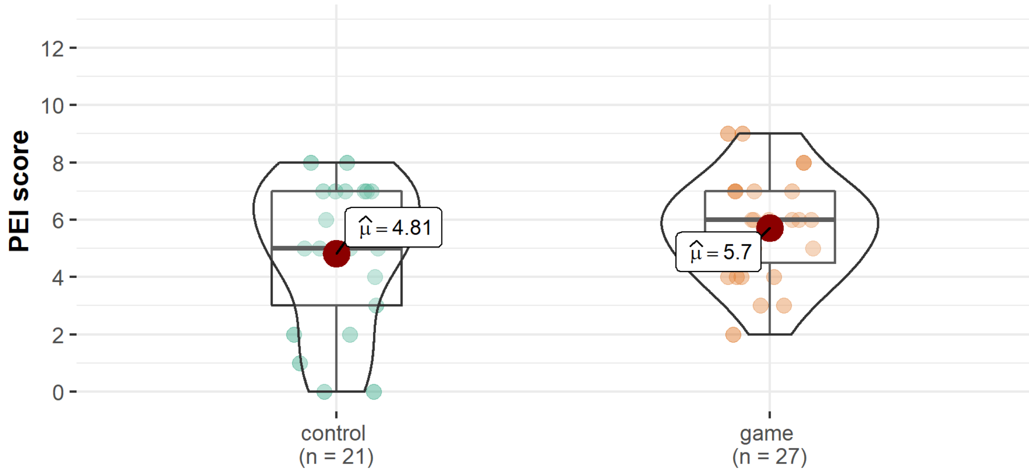

Figure 9. Results of Patient Enablement Instrument (PEI).

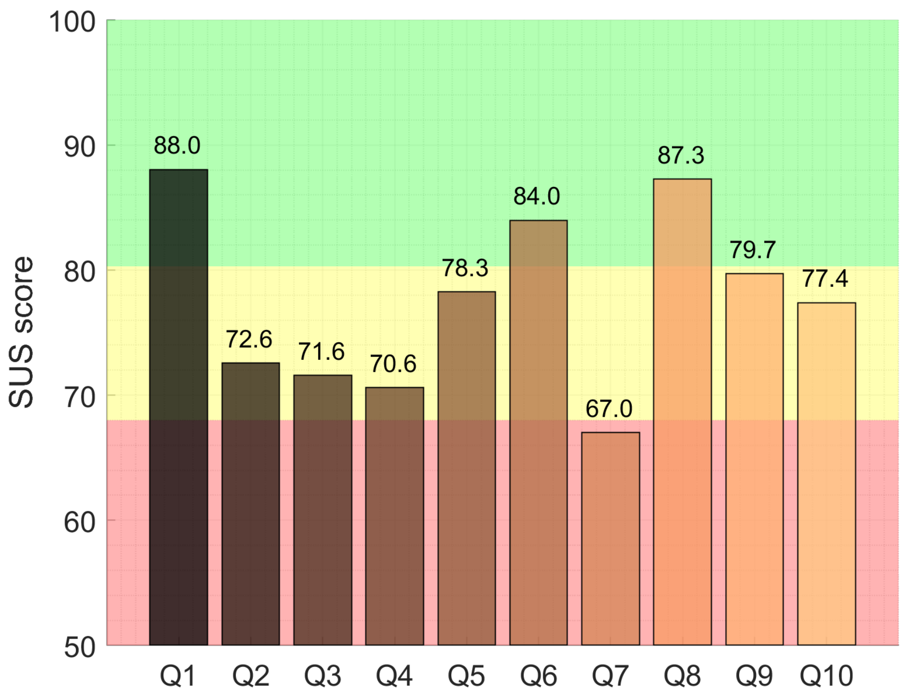

Figure 10. Results of System Usability Scale (SUS): Red—poor, yellow—good, green—excellent scores.

4. Discussion

The mean score for patient enablement reported was 5.7 among those taking part in the intervention (game) group, compared to 4.8 in the control group. The level of patient enablement in the intervention group corresponds to previously published studies. In a study in a primary care setting in Lithuania, the average reported patient enablement was 6.43% [42]. Similar a Croatian study reported a mean score of 6.6 [43]. Slightly lower levels have been reported from Sweden, France, with levels ranging between 3.0 to 5.06 [44] and [45]. Patient enablement highlights patients' important role in their own care where patients understand their health conditions and are able to participate in self-care or shared decision-making [46]. The original PEI assesses change in patients' ability to cope, and their understanding of their disease, following a consultation [47]. We used a modified version of PEI to evaluate the effect of a serious game developed to support knowledge acquisition regarding self- management strategies, and to support individuals in adopting behaviours that are more consistent with a better prognosis.

Previous studies have mainly focused on patient enablement as an effect of a physical general practitioner or nurse consultation, where consultation length, relational continuity and empathy have been shown to influence patient enablement [43]. Moreover cultural and linguistic differences are also likely to impact enablement, as patient enablement has previously been found to increase when patients consult for biomedical problems [42] and independently negative association is found with the complexity of consultation [48]. A possible explanation for the relatively high level in the current study may be that the content of the serious game is not intended to solve a complex problem but instead aims to increase the participant's knowledge acquisition regarding self-management strategies, i.e., it may hence be affected by the expectations that a patient has of a game compared to a healthcare professional consultation. The relationship between patient enablement and health outcomes have been investigated both in primary and secondary care and effects seem to remain after 1 month [48], whether the same long-term effect can be seen by a Serious game is not known. The result suggests that the MyRelief Serious Game seems to be able to influence patient enablement, however potential components within the serious game relating to the improvement needs to be further investigated.

5. Conclusions

This evaluation study focused on applying MyRelief serious game, aiming to address such challenges by providing an accessible, interactive, and fun platform that incorporates self-management, behaviour change strategies and educational information consistent with recommendations for managing low-back pain, based on self-assessment models implemented through ontology-based mechanics.

Functional disability measured by the Oswestry Disability Questionnaire (ODI) showed the statistically significant ($p < 0.001$) improvement in subjects' self-evaluation of their health status, which means that the clinical effect of the game was achieved The patient's ability to understand and cope with their disease, and life following the use of the Serious game was measured with Patient Enablement Instrument (PEI), which showed no statistically significant change, meaning that the game did not lead to knowledge transfer regarding the disease. The usability of the Serious game was evaluated with the System usability Scale (SUS), with the subjects providing the overall positive results (means SUS score is 77.6). The result suggest that the MyRelief Serious Game can influence patient enablement, however potential components within the serious game relating to the improvement needs to be further investigated.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

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Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

LBP	Lower Back Pain
VR	Virtual Reality
CP	Chronic Pain
Xbox	Xbox game console
cLBP	Chronic Low Back Pain
ODI	Oswestri Disability Index
Wii	Nintendo Wii game console
AI	Artificial Inteligence
MYMOP	Measure Yourself Medical Outcome Profile
MOOC	Massive Online Open Course
KTM	Knowledge Transfer Model
PEI	Patient Enablement Instrument
SUS	System Usability Scale

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