HIT to Escape the Lava: A Serious Game for High-Intensity Training in Patients with Chronic Low Back Pain

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Abstract: Chronic low back pain (CLBP) is a disabling condition that significantly limits overall functioning and quality of life. Although exercise therapy (ET) is a widely recommended treatment, patient adherence and motivation remain low, especially in home-based rehabilitation. This study presents the design, development, and initial evaluation of a gamified cycling exercise with high intensity interval training (HIIT) tailored for persons with CLBP. The game integrates cardiorespiratory interval training into a gamified environment to create a motivating and personalised exercise experience. Based on a formative expert evaluation, we conclude that the game concept provides a natural and motivating setting for a high-intensity cycling exercise. Some recommended design improvements to enhance the natural alignment of the game and the HIIT training have been identified. Further exploration of the game concept with patients is needed to determine its feasibility and effectiveness. The results of the current study will shape the design and development of digital health interventions that support motivating and enjoyable rehabilitation in and outside clinical settings.

1 INTRODUCTION

Chronic low back pain (CLBP) is one of the most common musculoskeletal disorders globally affecting persons of any sex and in all age groups (Airaksinen et al., 2006). It is responsible for the highest levels of disability of all diseases (Hoy et al., 2014). CLBP is associated with limitations in physical movement, leading to reduced daily functioning. Beyond physical impairments, CLBP is accompanied by psychological distress (such as fear of movement, anxiety, or depression), and social challenges (including work limitations and reduced participation in daily activities). Furthermore, these factors show a complex interaction, which contributes to reduced overall functioning and quality of life. Persons with CLBP may show lower physical activity levels and physical deconditioning. Among the available treatment options, exercise therapy (ET) is one of the most effective and widely recommended interventions for managing CLBP (Ferreira et al., 2023; La Touche et al., 2019), which has proven to lead to improved outcomes such as reduced disability and improved fitness, but still, the effects are relatively small (van Middelkoop et al., 2010).

ET encompasses a wide variety of modalities, often targeting different aspects of physical functioning. In the past few years, high-intensity training (HIT) which involves performing physical exercises at a high or very high level of effort, has been advocated as a particularly promising modality and feasible therapy, demonstrating beneficial effects on disability reduction and physical fitness in individuals with CLBP (Verbrugghe et al., 2019; Verbrugghe et al., 2021). The above-mentioned studies demonstrated the effectiveness of HIT in patients with CLBP in supervised settings.

Recently, a pilot study also found positive results for the effectiveness of HIT in CLBP patients in unsu-

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pervised settings (Meus et al., 2024), even with an off-the-shelf training app, including video guidance and reporting, that was not optimised for CLBP. Despite the clinical potential of ET, patients' adherence to such ET interventions generally remains a challenge, especially in unsupervised settings. Therefore, we are investigating how to fine-tune technology-supported HIT and better serve the needs of CLBP patients. First, a dedicated TechnoHIT app was designed for an ongoing Randomised Controlled Trial (RCT). The TECHNO-HIT trial, according to the protocol described in (Van Eetvelde et al., 2024) was approved by the FAMHP (consolidated opinion Federal Agency for Medicine and Health Products) (Ref. CIV-23-12-045154) and by the medical ethical committees of University Hospital Antwerp (UZA) (EC 6234), Jessa Hospital Hasselt (Jessa) (ID 024/047 - TECHNO-HIT trial), University of Hasselt (UHasselt) and University of Antwerp (UAntwerpen) and registered with trial number NCT06491121 at clinicaltrials.gov. Next to the mobile app for patients, a web-based dashboard for therapists to prescribe training and exercises to patients was elaborated.

The above-mentioned ongoing RCT uses what is called a "multimodal program = consisting of multiple training modalities combined into one program". These sessions include cardiorespiratory interval training, general resistance training and core muscle strength training, all at high intensity. Now, we are exploring gamification to enhance patients' motivation for home-based training (unsupervised settings). In this way, we investigate innovations which could be integrated in the post-RCT version of the software, while the ongoing RCT uses the pilot tested and specifically designed software for the whole protocol as mentioned above.

In this paper, we present the design, development, and formative expert evaluation of a gamified high-intensity interval training (HIIT) cycling exercise tailored for persons with CLBP, and meanwhile offering them a motivating and personalised exercise experience.

While designing and developing the Lava Escape Game, and performing the formative expert testing as described in this paper, the formerly mentioned FAMHP ethical committee approved upcoming testing with patients via an amendment.

2 BACKGROUND AND RELATED WORK

For many years, researchers have studied applications of gamification, which is defined as the use of game design elements (GDEs) such as rewards, triggers, progress tracking, and real-time feedback into a non-game context (Deterding et al., 2011; Segundo Díaz et al., 2022). A generally accepted definition of serious games in rehabilitation context is "video games developed for a primary purpose other than pure entertainment" (Bonnechère and Van Sint Jan, 2019). Similar concepts are denoted by different terms depending on their purpose and application context, such as exergames, games with a purpose, and game-based technologies. Serious games have the potential to serve as valuable resources in rehabilitation by making extended treatment more engaging and less monotonous.

Serious games and exergames were already successfully applied in various domains of physical rehabilitation, while targeting specific populations (Alazba et al., 2018; Costa et al., 2013; Luimula et al., 2019). In the scope of this paper, the goal of serious games is to enhance enjoyment and motivation of CLBP patients, by making their rehabilitation routine a personalised, interactive and enjoyable experience.

Over the years, serious games have gained recognition but mixed results have been reported about the effectiveness of these games. Several commercial virtual cycling platforms such as Zwift and Strava (Bentvelzen et al., 2022) gained significant attention, but they typically were developed for a large audience without special needs. Typical users of such platforms are professional cyclists, athletes, and healthy persons that like a cycling workout. To optimally serve these users, the training programs of these platforms feature different virtual environments that show a varying scenery to support workouts with a relatively long duration that do not necessarily benefit our target group. Virtual competition is supported as well in those environments, but game elements are limited. While above-mentioned platforms include features to define specific training protocols, their training programs mostly have a somewhat longer duration (e.g., 30 min or more) and as such they benefit from the diverse virtual environment. In contrast, the gamified HIIT cycling exercise we propose in this paper allows for tailored exercise for CLBP patients, such as short HIIT efforts. In our approach, variation in scenery is linked to game elements that trigger cycling intensity and contribute to sustain motivation of the patients.

As mentioned before, research has indicated that high-intensity and moderate-intensity exercise interventions are effective in pain management in CLBP patients (Meus et al., 2024; Verbrugghe et al., 2021). To the best of our knowledge, no research was done on gamification and HIIT for CLBP patients. However, researchers have investigated gamified cycling in other populations (Barathi et al., 2020; Haller et al., 2019; Kocur et al., 2021).

The research presented in this paper addresses the identified gap by presenting the design, development and formative expert evaluation of a gamified HIIT cycling exercise specifically designed for individuals with CLBP.

3 GAME CONCEPT: HIT TO ESCAPE THE LAVA

3.1 Objectives and Design Process

The objective of this research is to elaborate the concept of a cycling game for HIIT in CLBP patients. The training characteristic "high intensity" is essential in the specific protocol deployed in the current RCT. We selected the cycling exercise, one of the exercises which implement HIIT in the protocol, to investigate gamified alternatives. More specifically, we aim to explore the value of serious games to sustain patient motivation and improve therapy adherence. It is important to note that therapy adherence applies to the overall protocol, which includes other exercises next to the cycling exercise, and involves sustained training at home during a long period and for some patients even throughout their life. Depending on how the gamified cycling exercise is welcomed by experts and later on by patients, game concepts for other exercises of the training protocol could be designed and evaluated.

A user-centred design (UCD) approach is applied for this research. It is well-known that a UCD approach has the potential to enhance the success of a new application, especially for health-related applications (Harte et al., 2014). For the initial stages of the UCD process for the gamified HIIT cycling exercise, we built on the user needs, and results of usability testing and pilot testing, which were conducted with the participation of stakeholders (patients, physiotherapists, and doctors) for the mobile application and dashboard that are currently being used in the ongoing TECHNO-HIT RCT. The information collected with respect to the cycling exercise was particularly helpful to design the post-RCT gamified HIIT cycling exercise as presented in this paper, because both variations of the cycling exercise build on the same user needs and could be integrated in the same overall training protocol.

In a next stage of the UCD process, several possible game concepts were presented in low-fidelity prototypes realised in Canva. The focus in this stage was on visualising the overall structure and flow of the

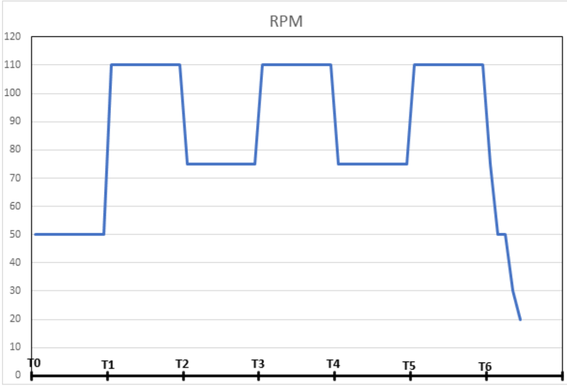

Figure 1: Theoretical evolution of RPM during the cycling exercise with alternating high intensity (HIT) and active rest periods.

game, scene transitions, and GDEs, and less attention was given to details of the graphical design. Several meetings (3) with rehabilitation scientists were organised to fine-tune the game concept and ensure its feasibility and safety in patients with CLBP.

The Lava Escape scenario presented in this paper was the first game concept to move to the next stage in the UCD process, being high-fidelity prototyping by means of the Unity game engine. The game is presented on a tablet, and able to communicate with the stationary bike (Flow Fitness Turner DHT2000i). The technical setup is depicted in Figure 3 and is described in detail in section 4.

3.2 Game Concept

The cycling exercise in the CLBP exercise protocol of the current RCT is a cardio exercise, requiring the patient to alternately cycle with high intensity (HIT) and active rest. The active rest phase involves cycling at a lower, more sustainable intensity (MIT), instead of stopping completely. Figure 1 represents the theoretical block wave of revolutions per minute (RPM) during this cycling protocol.

After a warming-up period ($T_0 - T_1$), periods of HIT ($T_{2n+1} - T_{2n}$) and active rest ($T_{2n} - T_{2n+1}$) are alternated, and the exercise ends with a cool-down period (T_6 till the participant finishes cycling). In total this takes about 10-15 minutes when performing the whole cycling exercise according to the current protocol. Personalised resistance settings for the bike, which have been determined previously together with a physiotherapist/researcher based on the participant's physical fitness, are set up before starting the cycling exercise. These personalised settings ensure reaching HIT at 110 RPM and active rest at 75 RPM. In practice the RPM does not instantaneously change between RPM of 110/min and 75/min, but with some de-

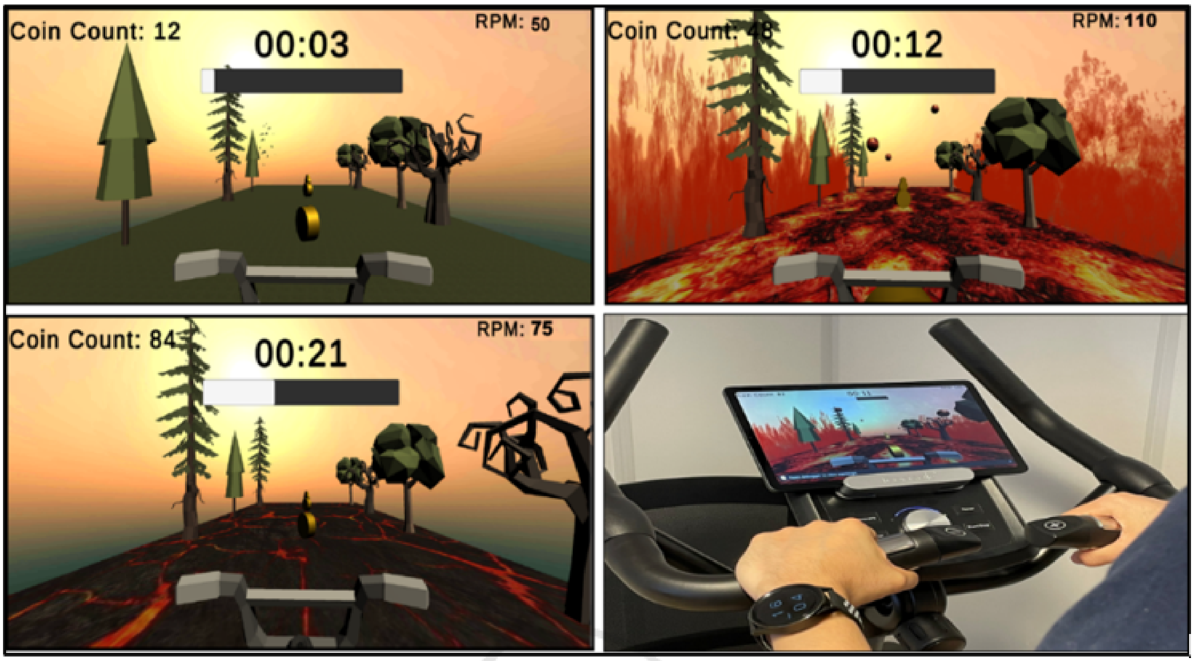

Figure 2: Lava Escape game scenes for warm up (top left), HIT (top right), active rest (bottom left), and the tablet with the game mounted on the stationary bike (bottom right).

lay which depends on the participant's cycling. Further in this paper, in the Results section, we will give concrete examples of the RPM evolution of participants during the gamified cycling exercise.

The general idea underpinning the game concept which we call "HIT to Escape the Lava" or "the Lava Escape game" in the context of this paper, is that the flow in the game should indicate when the user needs to enter a HIT respectively an active rest phase. For the participant, this happens concretely via visual information such as changing scenery in the game, and via upcoming game elements such as triggers (which will be explained in detail below). In this way, we intend to realise a more natural flow in the game leading to enhanced engagement with the game scenario, as opposed to explicitly instructing the user to go for a HIT or active rest period at some point in time.

In this Lava Escape game, a natural disaster scenario, that shows approaching fireballs and lava, is imagined to be an intuitive context to realise such a game concept. While the specific Lava Escape game concept as presented in this paper mostly contains negative triggers, including frightening lava surface and approaching fireballs which prompt the participant to cycle at high intensity to avoid the lava, we are also experimenting with totally different scenarios with positive triggers. Details on the other scenarios are beyond the context of this paper.

Figure 2 shows the different scenes that appear during the Lava Escape game. The Lava Escape game follows the same alternation of HIT and active rest as the cycling exercise that is integrated in the current RCT supported by the mobile app as (Meus et al., 2024) provided evidence that this protocol – in combination with the other exercises for low back pain in the RCT protocol – is effective for CLBP patients. Once the Lava Escape game will be integrated in the post-RCT application, it is planned to have 10 levels, each one representing a different length of the HIT bout during cycling and offering different rewards. Patients will progress to the next level after completing at least two full training sessions, consisting of cycling and other exercises.

As the intervention/therapy eventually involves gamified cycling using a stationary bike, the in-game experience simulates cycling on a straight path. This decision was taken together with rehabilitation experts to prevent unnecessary moving or turning, which could potentially lead to discomfort in CLBP patients of the target group. The absence of obstacles on the path in the game is also a deliberate safety measure, as the expectation to hit a virtual object could induce real pain in persons with CLBP.

3.3 Game Design Elements

GDEs (Segundo Díaz et al., 2022) are fundamental building blocks for designing a game. Well-designed elements not only capture players' attention but also sustain interest in the game (Reeves and Read, 2009). Different GDEs such as rewards, triggers, and feedback are used in the Lava Escape game.

3.3.1 Rewards

Rewards such as coins or stars were used to integrate the principle of positive reinforcement. Positive reinforcement is known to be effective in encouraging players (Reinschluessel and Mandryk, 2016) and has been used in several exergames, increasing player engagement and commitment, and therefore improving exertion (Ketcheson et al., 2016).

3.3.2 Triggers

In the lava Escape game, triggers are important for motivating patients to cycle at the expected intensity indicated by the RPM, and as such triggers function as essential cues forcing urgency and encouraging patients to pedal faster or slower. For instance, approaching fireballs and the lava surface should trigger the participant to pedal faster and thus reach HIT. In this way, we intend to implement the envisioned stimulus-response sequence by providing triggers and rewards in the game to the participants, rather than directly providing textual or other visual instructions to reach a certain training intensity.

3.3.3 Feedback

In game design for diverse contexts of use, feedback reveals the status of the game and the level of the user's performance and plays a crucial role in achieving more effective engagement. It also helps in enhancing motivation and acts as a positive reinforcement of user behaviour and achievements, thus enhancing the users' perception of competence (Birk et al., 2016), and self-confidence (Debackere et al., 2023). The feedback can be given via intrinsic and extrinsic formats (Zuki et al., 2022). In the Lava Escape game, patients receive feedback based on their exercising efforts and gaming performance, which hopefully motivates them to complete their training according to the protocol. While playing the game during the cycling effort, feedback is given with visual cues such as the displayed RPM indicator and audible cues to indicate the start of a HIT scene. Users also receive an overview of their performance after finishing the game.

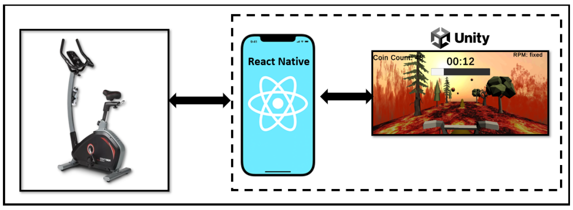

Figure 3: Technical setup with stationary bike, Unity 3D game running on a tablet, and a React Native smartphone application to establish a communication link.

4 TECHNICAL SETUP

The stationary bike used in the current setup is the Flow Fitness Turner DHT2000i which allows communication via the Bluetooth Fitness Machine Service (FTMS) protocol as presented in Figure 3. The Lava Escape game is realised in Unity 3D (version 6000.0.47f1) and runs on a tablet computer, as this device is commonly available at home. It is technically feasible to replace the tablet by a smartphone at home, but the small display of a smartphone makes triggers harder to discover. Similarly, it would be technically feasible to use a laptop to run the game, but the tablet is easier to mount in front of the bike's display. When the setup is installed in a rehabilitation centre, a larger display would enhance the feeling of immersion in the game environment.

In order to establish a two-way communication protocol between the Lava Escape game and the stationary bike, a React Native (RN, version 0.79.2) smartphone application was realised. One of the benefits of developing in React Native is that it allows having a single code base that works on both Android and iOS devices. The RN app connects to the bike via Bluetooth, and is able to retrieve real-time data such as RPM of the bike, Heart Rate (HR) of the person who is cycling, and the actual setting for the bike's resistance. The RN app makes sure these data are sent via Bluetooth to the Lava game implemented in Unity, and vice versa, personalised settings in the game are sent to the bike via the RN app.

When a user notices a trigger such as a fireball and starts pedalling faster (or sustains a fast pace), the Lava Escape game monitors the RPM retrieved from the bike, and can thus detect when this patient assumes and reaches HIT. The main reason why we call the Lava Escape game in this stage a high-fidelity prototype (developed in Unity) and not yet a full application, is because the data storage is a temporarily local solution for research purposes and it is not yet integrated with the database that is currently used for all exercise data in the ongoing RCT.

In this paper, an initial, formative evaluation of the game in a lab-based setting is described, using the same stationary bike used in the RCT. A similar setup could be available in home-based training in later stages of research and deployment in practice.

5 FORMATIVE EVALUATION

The main aim of the evaluation step reported in this paper is to evaluate the initial usability and feasibility of the Lava Escape game concept in the context of CLBP exercise training. In this stage of the UCD process, the Lava Escape game concept is evaluated on itself, and effectiveness of the game and feasibility of similar game concepts will be evaluated in a later stage, in the broader context of all exercises supporting the HIT RCT protocol. Before evaluating the Lava Escape game concept with patients, we performed an initial, formative evaluation of the “HIT to Escape the Lava” game with experts. Indeed, doctors and physiotherapists are well-placed experts to initially evaluate the feasibility of the game concept for their CLBP patients, and together with human-computer interaction (HCI) experts their feedback is formative with respect to the game’s usability. Beyond the scope of this paper, additional evaluation with representative patients – and after integrating the feedback collected in the current formative evaluation - is crucial to assess the value of the game in the CLBP exercise training.

5.1 Procedure

The initial formative evaluation of the Lava Escape game was organised as lab-based evaluation in individual session. Each expert participated in one evaluation session. Depending on the working place of the participating researchers and healthcare professionals, sessions were organised either in Hasselt University or Jessa Hospital(Hasselt, Belgium).

Experts were invited to interact with a functional high-fidelity prototype of the Lava Escape game. In order to restrict the overall time needed per test session, and to still realise a comprehensive evaluation of the game concept, a shortened cycling protocol was applied. Instead of a HIIT cycling exercise of 10-15 minutes as part of a real training session compliant with the RCT protocol, the experts would cycle for about 3 minutes during the formative evaluation session. The experts were invited to play 3 levels, with 60-seconds allocated for the first game level and 30 seconds for levels 2 and 3. The testing session consisted of a 10-second warm-up, followed by alternating HIT and active rest intervals, and concluded with a 5-second cool-down. Within this time frame, the participants experienced a total of 3 HIT bouts and 2 active rest bouts resulting in a total duration of 2 minutes and 30 seconds.

Overall, sessions were announced to last max 30-45 minutes, including welcoming of the participant, and personalising their resistance settings within the game based on participant’s physical fitness, completing a background questionnaire, a few minutes cycling to test the Lava Escape game, followed up with an IMI questionnaire and a semi-structured interview providing feedback on various aspects of the system (such as general game concept, user experience, discovery of scene transitions/triggers/rewards in the scenario, expected motivational effect), and finally debriefing and thanking participating experts.

5.2 Participants

Given the objective of the study to collect formative feedback on various aspects such as feasibility of using the Lava Escape game in CLBP patients and its perceived usability and motivational effect, participation of experts with diverse professional backgrounds was envisioned. To cover the different perspectives, recruitment targets were: at least one medical doctor specialised in physical and sport medicine and rehabilitation, between 6 and 10 physiotherapists or academic researchers in rehabilitation science, and 3 to 6 HCI experts. Recruitment of HCI experts and rehabilitation scientists in Hasselt University was done by a principal investigator in HCI (co-author), and recruitment of hospital-based caregivers (doctor and physiotherapists in Jessa Hospital) was facilitated by one of the physiotherapists who is involved in the project consortium. For the overall project, medical ethical committee approval was achieved for user needs detection, software design and initial evaluation and the overall RCT. Taken this into account, and the professional relationship of the invited expert participants with the consortium, no specific ethical committee approval was required for the formative evaluation of the Lava Escape game.

5.3 Measurements

In this formative evaluation of the Lava Escape game by experts, data was collected using a combination of different measurement instruments: an ad hoc background questionnaire, a standard questionnaire to evaluate among others, motivation, and a semi-structured post-test interview. The ad hoc background questionnaire collected demographic information (age and gender) and participants’ prior experience relevant to gamified cycling, such as former experience with exergames and digital literacy in general. The answers on this questionnaire are mostly used to interpret the other collected data.

The Intrinsic Motivation Inventory or IMI questionnaire (McAuley et al., 1989) is a well-established and widely used questionnaire to access participants' motivation in experimental settings. IMI has frequently been used to assess motivational aspects in digital health context, next to its use in other application domains. IMI includes 7 dimensions, and the 4 most relevant dimensions in the context of this study were questioned: Interest/Enjoyment, Effort/Importance, Pressure/Tension, and Perceived Competence. Some IMI items are negatively worded and therefore the scores for those items are reversed before averaging. Items are rated on a 1 - 7 Likert scale, with 1 corresponding to "Not at all True" and 7 corresponding to "Very True". Mainly the first dimension, Interest/Enjoyment, is directly related to participants' motivation and enjoyment while playing the game. Based on our prepared evaluation of the full RCT, we decided to split the Interest/Enjoyment dimension into two versions, and question the participant on both of them. The items in one variant were specifically targeting the training session as such, whereas the other version focuses on game-play. By presenting the items in both variants, we hope that participants are more conscious on the perspective they take when answering the question, e.g., they might not like to cycle but still like the game concept. The dimensions Interest/Enjoyment, Perceived Competence and Effort/Importance of the IMI questionnaire are positive predictors of the represented concepts and enjoyment while playing the game, and therefore should have a higher value, whereas Pressure/Tension is theorised to be a negative predictor of gaming enjoyment/motivation, and should have a lower value (McAuley et al., 1989).

The post-test semi-structured interview with the experts covered both aspects of feasibility to use the Lava Escape game (and similar game concepts) in patients with CLBP, and aspects of general user experience and acceptance. It was decided to integrate the user experience questions in the interview rather than using a special-purpose usability questionnaire, because at the end the experts are not representative for the end users, CLBP patients. Via the dialogue with the professionals in the interview, it is easier to distinguish whether they express their own judgement on user experience versus their view on patients' expected user experience.

An important point of attention in this formative evaluation was the recognition of and reaction to triggers and rewards in the Lava Escape game, by the participants. While the participants are experts and not directly representative for CLBP patients, we do use their formative feedback on these GDEs to fine-tune the design of the game concept. Therefore, it is beneficial to integrate these questions in the semi-structured interview, as it allows to clarify concepts such as triggers and rewards and listen to the interpretation of the participants.

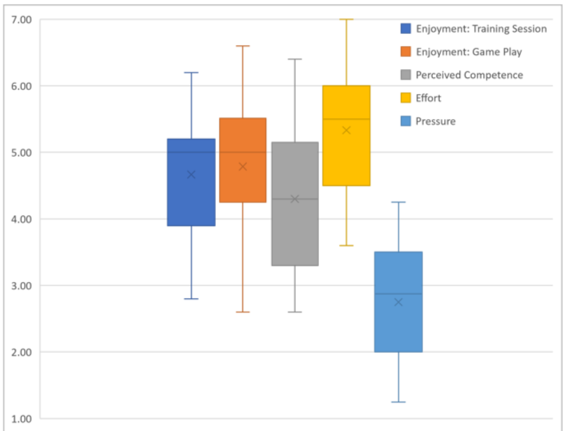

Figure 4: Box plots from IMI results.

6 RESULTS

6.1 Participants Characteristics

A total of 12 experts (ages 20–40) participated in this study, maintaining an overall gender balance (6 male, 6 female). Based on their expertise, we classify them as follows: 4 participants were HCI experts (2 male, 2 female) and 8 participants were rehabilitation specialists (4 male, 4 female), either doctor or physiotherapist. Out of the 12 participants, only 2 had previous experience with exergaming or cycling in Zwift. One of them is a doctor, and he is also a regular user of Zwift. The other participant that indicated familiarity with exergaming has tried gamified cycling before but is not a regular user.

6.2 IMI Results

The quantitative results of the IMI questionnaire are summarised in Figure 4. When comparing the scores for both variants of enjoyment, it shows that the scores for "Enjoyment: Game Play" (Mean = 4.79, S.D = 1.10) were relatively higher than those for "Enjoyment: Training Session" (Mean = 4.67, S.D = 1.04). The scores of the Effort dimension in IMI (Mean = 5.33, S.D = 1.01) indicate that at least part of the participants experience completing the HIIT game as a tough physical exercise. It is positive to conclude that the Pressure scores (Mean = 2.75, S.D = 0.98) are rather low, suggesting that the participants do not feel stressed despite the fact that a lot is happening at the same time by integrating HIT in an interactive game. Compared to other dimensions of IMI, the scores for Perceived Competence (Mean = 4.30, S.D = 1.20) reveal slightly more variation (as indicated by the standard deviation).

6.3 RPM Analysis

To explain the HIIT protocol of the cycling exercise, we presented the theoretical block wave of RPM in section 3.2, Figure 1, with the alternations of HIT and active rest bouts. At this point, we can create a similar graph based on the actual RPM data of participants as collected during the formative evaluation. Figure 5 presents the comparison between theoretical block wave of RPM (blue dotted line), with the alternations of HIT and active rest bouts, and in orange solid line the actual RPM evolution triggered by the Lava Escape game for one particular participant. Obviously, the actual RPM graphs does not match exactly the theoretical block wave. The trajectory of the graphs highlights that, initially, it took the participant some time to understand the game. The first few seconds in the graph show the fluctuation in the RPM, but once the participant understood the triggers, they responded correctly to the alternation of HIT and active rest by adjusting the RPM accordingly. In that way, the graph with actual RPM gradually resembles more the theoretical block wave, but will not exactly match the sharp edges of the theoretical curve due to triggered RPM changes not happening instantaneously.

As described previously in section 5.1 on the evaluation procedure, the participant played 3 levels – separated in the graph by the dashed vertical lines in Figure 5. After the 60 seconds of the first level the participants took a small break during which the RPM approached zero. After the break they played levels two and three for 30 seconds each, with a break of five to ten seconds in between.

6.4 Interview Results

The qualitative results collected from the semi-structured interviews situate the experience of the participating experts. All of them appreciated the game concept, found it motivational and expected it to be motivational for their patients. The game was considered suitable for home-based training of CLBP patients. Each individual expert noticed changes in scenery related to the intensity of the exercise, as well as the triggers such as fireballs, but not all of them responded in the same way. Interesting to notice, is that we observed two types of response. Six rehabilitation experts, and two HCI experts almost immediately (while being in the first game level) discovered the purpose of the scene change and the triggers, so they started pedalling faster when noticing fireballs to reach HIT. The other four persons did not discover this expected behaviour-response spontaneously and needed a hint.

Surprisingly, one person interpreted it almost the other way around, namely that they had to keep on pedalling fast to avoid that the scene would change. All participants recognised the coins as rewards but none of them noticed the coin count that was continuously displayed as numeric information. Both triggers and rewards were considered to be motivational elements. One participating rehabilitation expert mentioned “The triggers and rewards distract the attention from the HIT as such, which is a good thing as HIT can be hard to perform for some patients. They are distracted from the effort it takes, but at the same time they keep on going.”

Physiotherapists working in the hospital like the idea of doing the training with support of the game as compared to patients’ normal training session. They appreciated having different rewards (e.g., stars and coins) in the game as they will likely be motivating for patients. These physiotherapists are working with the patients on a daily basis and one of them assumed that initially it would take a while for patients to understand the game, but that they would enjoy it under the condition that proper instructions and explanations would be given.

7 DISCUSSION

The formative evaluation of the Lava Escape game by experts provided interesting insights to improve the designed game concept before actually testing with the target group i.e., CLBP patients. The applied mixed-method approach for evaluation with expert users was beneficial to gain insights. Indeed, the qualitative results from the interviews are not only useful in itself, but they also help to interpret the quantitative results.

7.1 Summary of Results

The two variants of the IMI questionnaire’s enjoyment dimension, reveal that perceived enjoyment related to the game outperforms enjoyment experienced by the training as such. This could indicate that the

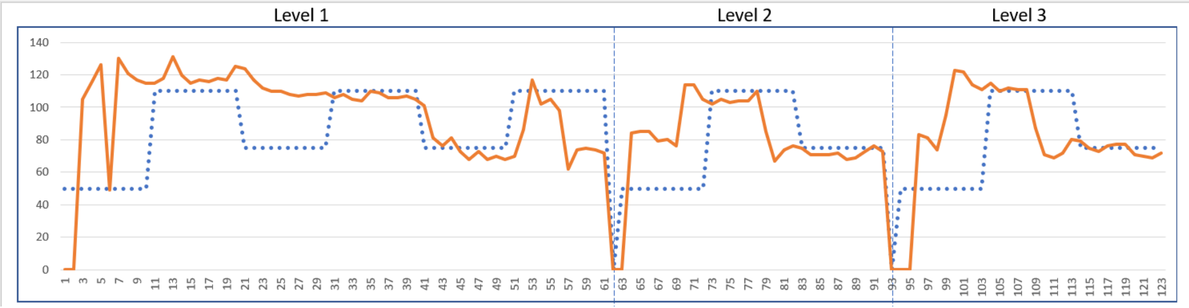

Figure 5: Comparison between theoretical RPM (blue dotted line) and actual RPM (orange solid line) graphs.

participants did enjoy the game aspect without thinking all the time about actually doing the cycling effort. The interviews confirm this finding. Obviously, we have to be careful with this interpretation and repeat the evaluation of both variants of enjoyment with representative patients at a later stage. Nevertheless, these results on enjoyment achieved with experts are expected to transfer to patients because the required cycling effort, such as the RPM to reach the HIT level, is personalised for each participant in the evaluation. Furthermore, the need for personalisation is confirmed by the quantitative results of the Effort dimension of the IMI questionnaire, and during the interview some experts emphasised the importance of fine-tuning the expected effort of the patients.

In practice, integrating the gamified HIIT cycling exercise in the overall TechnoHIT training platform for CLBP patients, would be feasible because physiotherapists will assess the patients' characteristics and set the patient profile in the application. Also, it should be noted that a HIIT cycling exercise not only could but even should challenge the patients to achieve the desired rehabilitating effect. The variation in scores for Perceived Competence was also confirmed in the qualitative results by some remarks of participants. Most likely this result is influenced by the confusion some participants experienced to immediately interpret triggers in the game, as follows from the interviews.

Analysing the RPM graphs contributed to objective insights in how they gradually discovered the triggers for the different stages in the HIIT game. These findings were confirmed in the interviews, when participating experts elaborated on how they tried to interpret the GDEs and how their understanding evolved in the next few minutes of cycling.

A general finding from this formative evaluation, also confirmed by those participants who fully understood the expected behaviour, is that transitions to and from HIT should be indicated slightly more explicitly. Examples given were additional explicit visual cues, such as icons (next to the implicit visual cues such as scene changes and triggers) or pop-up instructions. Furthermore, it was suggested to clarify the auditive cues (harder sound while HIT is done) before starting the game. Similarly, the different scenes could be highlighted beforehand, so the users know what to expect. To retain the natural flow in the game and explorative game behaviour, these additional cues and extra instructions could be limited to first game level. This need for instructions aligns with existing literature that indicates that instructions could be used to increase the playability of games and to enhance players' learning process in video games (Cao and Liu, 2022). To find a good balance between explicit instructions and a game flow that only builds on triggers, we decided to selectively integrate instructions. More specifically, an instruction tab was added to the main menu, but in-game instructions were only integrated in the first level to support users in getting familiar with the trigger-based game concept.

7.2 Limitations

The study has some limitations including the fact that the game was not yet evaluated with real patients, but it was a deliberate choice to include the formative expert testing in the UCD process. A next stage therefore should involve representative CLBP patients in the evaluation process. The scale of the formative evaluation is rather limited with 12 expert participants, but given their diverse profile and the formative stage in the UCD process, the scale is acceptable.

8 CONCLUSIONS AND FUTURE WORK

This study presents the design, development and initial formative evaluation of the Lava Escape game, a HIIT cycling exercise, that is tailored for individuals with CLBP. The game alternates between bouts of high-intensity training and active rest, and aims to enhance patients' motivation, adherence, and rehabilitation outcomes. The change in presented scenery and triggers, dependent on the actual training bout and its cycling intensity, may keep the patient focused and break the monotony that is often associated with rehabilitation routines. The game uses resistance settings that reflect the patient's general fitness and incorporates GDEs and feedback to adapt to their individual performance, offering a more personalised exercise experience.

Future work includes incorporating the feedback found in this study in the game, exploring game concepts with more positive triggers and evaluating different game concepts for gamified HIIT cycling with CLBP patients. Integration into the broader home-based rehabilitation platform for CLBP is envisioned. Fine-tuning the game to treadmills or other training equipment allows supporting a broader range of HIT exercises, and makes the game even more suited for other user groups, which is useful because HIT and cardio exercises are part of many rehabilitation protocols and training programs.

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