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# Gameful Design of an Application for Patients in Rehabilitation

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The design process of any interactive application is an important part of its lifecycle, since it largely defines its structure, means of interaction with the users and its actual content. In the case of applications related to medical uses and self-help, it is even more important, given the aims of the application, the diversity of target users and the urgent need for increased retention. In this article, we present a gameful design process for a mobile application targeted toward patients in rehabilitation, implementing concepts related to increasing user rapport and motivation through gamification, and means to offer guidance and personalized services to improve user experience. Both gamification and personalization build on narrative concepts, by putting patients in the place of a "hero", offering them the opportunity to overcome "challenges" and receive a clear view of their progress (a.k.a. a "hero's journey"), both in terms of physical and mental condition. Finally, we discuss measurable indicators used to evaluate the application in terms of the progress that patients showed, their motivation and interest, and degree of adherence to the exercise plans.

**Keywords: gameful design, e-health, serious games, gamification, mobile application, adaptation, motivation**

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## 1. INTRODUCTION

Mobile applications related to health and self-help have become increasingly popular over the past few years. Factors which contributed to this include the emergence of inexpensive, yet powerful mobile devices (such as mobile phones, tablets, and smartwatches) which users can carry during exercise, outdoor walks or indoor living and work, energy-efficient sensors which provide robust physiological signals offering insight to the users' physical and emotional condition (Karpouzis and Yannakakis, 2016), and the users' increased familiarity and trust to such applications. The COVID-19 pandemic also helped increase the popularity of e-health applications, since they could eliminate or minimize the need for social contact when exercising, while maintaining a substantial level of performance when it comes to their users experiencing positive results (Marchant et al., 2021). An important characteristic of health-related apps, which tells them apart from those related to productivity or entertainment, is that they need long-term engagement from the part of the users in order to provide any meaningful results, since physical condition improvements may take weeks to become noticeable, while skipping one's exercise schedule for more than a few days may result in losing all progress made. In addition to this, the users' physical and emotional state (Cowie et al., 2011a,b) may be at stake when using an e-health application, since it challenges both their physical and mental abilities and may cause negative emotions when targets are not met; as a result, any information and suggestions presented by the app to the users needs to be reliable and timely, preferably provided or verified by a trained physician and adapted to the needs and particularities of each user.

In this article, we present the design principles for a tablet-based application targeted toward adults enlisted in a rehabilitation programme; the application has been developed in the framework of the MediLudus[1] project. There is no strict age restriction for the users we target, resulting in a requirement for the application to be elaborate, engaging and effective for young adults and elderly users alike. In terms of physical and mental condition, our focus group does not include patients with chronic mental impairments, such as dementia (Maskeliūnas et al., 2019), or athletes on a training program (Guggenberger et al., 2021); we mostly focus on rehabilitation after injuries and accidents, with low to medium impact on the patients' mobility, likely to be improved through a non-surgical intervention, patients who suffered mild strokes, with limited, yet noticeable impact on their mobility, similar to Noveletto et al. (2018), and people over 50, who need to exercise regularly to maintain their general physical and mental condition. An important requirement for our design was to make sure that physicians or general practitioners would be able to prescribe specific activities for each patient, accompanied with measurable objectives and progress indicators; our system should be able to suggest parts of those personalized plans, which would then be approved by the physician. For these reasons, we opted to employ notions related to *gameful design* or *gamification* (Deterding et al., 2011). Gameful design does not necessarily utilize games or game-based activities to engage and motivate users, but it does lend concepts from digital games and applies them to activities which are not primarily designed for entertainment. A general list of principles from Game Design which are relevant here (Doukas et al., 2008; Chou, 2019; Schmidt-Kraepelin et al., 2020) includes:

1. Create elaborate, achievable, and rewarding goals
2. Design for user emotion
3. Create responsive and robust interaction
4. Make fun activities and combine them into games
5. Clearly indicate the next action
6. Provide clear and immediate feedback
7. Balance high perceived skill with high perceived challenge or difficulty.

Many of these concepts are related to the functioning of a guidance application as a form of narrative, where the user/patient assumes the role of the *"hero"* or main character who has to achieve a number of goals (in our case, set by a physician according to the patient's medical history and profile, cf. Koivisto and Hamari, 2014 or Jia et al., 2016) and navigate though different choices (the tools or gameful activities available to them). The final principle in this list essentially represents flow (McCallum, 2012; Mekler et al., 2017), i.e., a state of mind where users are so focused on the task at hand that they lose track of time and fully concentrate their mental and physical abilities; flow (Nakamura and Csikszentmihalyi, 2014) is often associated with adapting the difficulty of the tasks assigned to a user (or the obstacles and challenges a game hero has to overcome) according to the user's skill, so they don't become frustrated or bored, should the tasks be too hard or too easy for them, respectively (Karpouzis et al., 2015). In the following sections, we discuss how our design implements these concepts and provide details on our actual choices with respect to implementation; more specifically, Section 2 discusses gamification and gameful design to increase user motivation and provide a fun experience, Section 3 provides insight on the role of the app and the users' progression as a narrative, and Section 4 discusses coaching as a guidance on what to do next in the application and a form of immediate feedback (which is also provided *via* gamification).

## 2. GAMIFICATION AND USER EXPERIENCE

The concept of *Gamification* was initially described by Deterding et al. (2011) as the utilization of gameplay-related measurable concepts in commercial or educational applications. Games researchers often associate *games* with the evolution of a *narrative*, a general purpose or aim to be completed by a *hero* (usually controlled by the player) and the interference of enemies or adversaries who attempt to either reach the same goal before the hero or just prevent them from accomplishing it; this essentially means that by merely introducing gamification in, for instance, an application that enables users to place an order for food or buy items from an online shop, that application does not become a game. In addition, the general concept of a game also refers to *strategies* that need to be defined and improved by players, so as to accomplish the goals of the game, as defined by its *win conditions*. Most applications, either for mobile devices or desktop computers, that include quizzes or educational content would fail to comply with that definition, but are generally referred to as games, mostly because of their competitive nature and the relevance of the user experience (Asteriadis et al., 2012; Karpouzis et al., 2015) to sports-related activities or multi-player board games.

The benefits of introducting gamification depend of the characteristics, traits and preferences of the targeted users (Koivisto and Hamari, 2014) and the context of the application (Rajanen and Rajanen, 2017), and may alter both the user experience, as well as how users interact with the application, feeding back to its design and functionality. From the users' point of view, the first level of benefits has to do with receiving instant feedback with respect to a specific activity in the application (action or choice), feeling the sense of progress and experience, and the encouragement to continue using the app in a certain manner or performing original, advanced actions. When it comes to designers, the choice and deployment of gamification concepts should motivate users to keep using the application or remind them to come back to it, if they've taken a break; gamification should also present elaborate information on the actions users take and their results, as well as suggest (but not necessarily enforce) the next user actions or choices. In the context of user rewards, those usually depend on the actual behavior to be commended (e.g., sustained use of the app or accomplishment of goals), but more importantly, may reflect the level of maturity of the app itself: for example, when an application is rolled out, designers usually opt to reward the recruitment of new users by existing ones and, when this is accomplished, switch

[1]MediLudus project web site, https://mediludus.eu/en/.

to promoting the creation of new quality content. In essence, the selection of user actions to promote, suggest and rewards depends on the priorities set by app designers and affects the tools included in the gamification scheme.

Another important aspect related to selecting gamification techniques for an application or service has to do with how user behavior is affected when tangible or virtual rewards are taken away or become repetitive (Hwang and Choi, 2020). If the design of the gamification scheme correlated proper use of the application (and, through it, behavior change) with supplying rewards, then the risk of users reverting back to their old ways is far from negligible. This reaction from the part of the users has to do with whether and how they are motivated to use the application properly, given that motives can either be intrinsic/endogenous or extrinsic: the latter case mostly refers to tangible rewards or goods, e.g., when users are rewarded with money, free products or reduced prices, but also includes virtual rewards, such as recognizing their effort *via* a leaderboard. In most cases, self-help or improvement applications, such as those related to health or education) should focus on intrinsic rewards (Mekler et al., 2017), since those are associated with behavior changes that affect the users' physical or mental state and their self-confidence and do need to be asserted by tangible rewards (McCallum, 2012).

## 2.1. Points, Badges, and Leaderboards

The most usual manifestation of gamification has been a combination of Points, Badges and Leaderboards, collectively referred to as PBL (Hamari et al., 2014). In this context, whenever users complete specific activities or follow usage patterns (e.g., use the application every day for a complete week), they are rewarded with *points*, in the same manner that game players win points whenever they complete a quest, defeat an opponent or complete a game level. From the point of application designers, this workflow helps in motivating users to use specific tools or complete activities or, in general, interact with the application in the way it was designed to; from that of users, the instant feedback of receiving points or badges guides them toward the correct way to use the app to achieve their goals, in the same manner that they are guided toward the "win condition" in a game, The comparative amount of points users receive for an action corresponds to the importance of the actions they performed and may change during the course of the application life-cycle: for instance, in the context of e-health applications, it may be more important to reward uninterrupted use for a predetermined time than increased performance in a single application session (Mekler et al., 2013; Costello, 2020).

Besides comparing different in-app activities, which are rewarded with different amounts of points and, thus, reflect the priorities that users should respect, another gamification instrument usually found in games is the reverse ranking of users in *leaderboards* (Mekler et al., 2013). A leaderboard offers users a more objective measurement of their overall accumulated performance since they first used the app and a sense of progression, based on how quickly they climb up the leaderboard. A variant of the usual player/user ranking in leaderboards (see **Figure 1**[2] for an example of a multi-tiered leaderboard) utilizes only a subset of all players, either the top performers and the vicinity of the user in question (e.g., shows the top 10 and then the users whose point tally is close to that of the user) or shows the percentage of users with point tally less than the user in question (e.g., *"you are better than 65% of all users"*. These two variants may be preferable in the early stages of deploying a newly released application, when users are usually scarce; they also offer qualitative information to users by comparing them with the majority of their peers and offers the sense of progress not only by the amount of points they have accumulated but also through their improved position in the rankings.

While points and leaderboards reflect continuous or sequential choices or actions in an application, rewards in the form of *Badges* correspond to specific achievements with respect to the users level of familiarity with the app or their improved behavior (Koivisto and Hamari, 2014; Su and Cheng, 2015). In order to avoid repetition, which would lead to reduction of its perceived value and novelty as a reward, badges are usually awarded once to each user, when they first complete each specific achievement: e.g., after their first login, to familiarize them with the app reward system, or after a month of continuous compliant use of the app. An improvement of this instrument utilizes *tiers* for each badge, usually in the form of numerical progression (e.g., "Level 1", "Level 2", etc.) or a label progression (e.g., military ranks, "Novice" to "Master" to "Expert", etc.), as shown in **Figure 2**. This sense of progression vividly illustrates the value of badges within a gamification scheme, as a means to visualize the evolution of users since they started using the app; badges also serve as a reminder of what is left to do in order to become even better with the app, as a list of rewards still left to claim or badge levels still left to progress to, and the actions or points tally necessary to obtain them.

# 3. BEYOND PBL

Gamification schemes based on a combination or flavor of PBL instruments have enjoyed immense popularity, especially in applications related to buying goods or services, mostly thanks to the straightforward nature of the rewards system with respect to specific actions or behavioral patterns. In essence, these instruments correspond motivation and rewards in gameful activities or digital games, where players are inclined to perform the actions requested by the app/game designers, either intrinsically (satisfaction, sense of value) or extrinsically (tangible rewards, recognition of their status).

A major issue with these schemes has to do with what happens to motivation and behavior change when rewards become repetitive or even obsolete (Dale, 2014). Besides decreased interest and users reverting to their old habits, in many cases users concentrating in amassing points and rewards, so they climb up the leaderboard ranking or complete the badge list, instead of focusing on behavioral change for their own benefit. This may happen, for instance, with personal training applications, where users may be rewarded whenever they log

[2]Laddercompetition Ltd., CC BY-SA 4.0, *via* Wikimedia Commons.

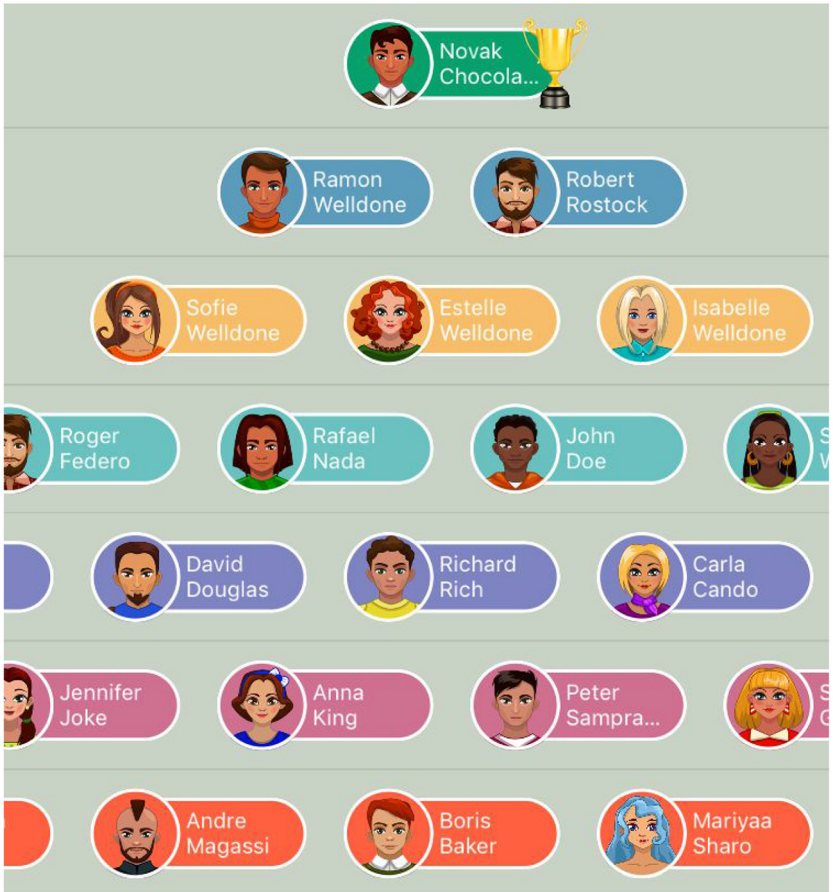


**FIGURE 1 |** Leaderboards can be used to present performance comparisons with other users.

on to the app: even though this scheme is designed to offer motivation to the user to use the app and go through a physical exercise programme, users may choose to log on repeatedly to earn more points, without performing any physical activity. This is referred to as "gaming the system" (Baker et al., 2004) and is an unwanted byproduct of these instruments being a gaming heritage, where player competition for the most points sometimes overcomes the motive to complete the game along its narrative and fulfil the hero's ultimate aim. The major issue with "gaming the system" is the lack of behavior change, which is ultimately the purpose of the app and its gamification scheme; this is extremely dangerous for apps related to physical or mental health and may be attributed to the lack of proper motivation from the app to the user and vice versa. Besides this, if the evolution of the user in the context of the app has to do only with points and badges, a visual representation of the "hero's journey" (Brown and Moffett, 1999; Chou, 2019) will not reflect any actual improvements and may lead to incorrect or even harmful decisions or counseling.

One way to avoid the negative consequences of users misusing the app to earn gamified rewards is to go beyond numerical or lexical descriptions of success, progress or achievements and include game *mechanics* in the gamification scheme (Oberdorfer and Latoschik, 2018). A major part of defining what constitutes a game is that of introducing elements of a *narrative* that connects the hero with a purpose or object of desire, with enemies or obstacles standing in the hero's way. Given that users are regarded as "the hero" of a gamified app, especially in the presence of personalization, a more advanced gamification scheme should also involve clear aims to achieve and obstacles to overcome. In the context of a self-help or e-health application, aims may be different for each user (Noorman-de Vette, 2019), either chosen by them (e.g., how much weight they want to lose within the next month) or assigned by the app or a practitioner after a consultation session or placement test. This approach is more likely to succeed since the chosen aims will be relevant to the user and their current physical or mental capabilities and may be adapted if their performance shows that they were too optimistic or easy to achieve. Besides choosing a clear aim, it is important to illustrate the necessary "win conditions" to achieve and maintain it through the application: these may correspond to measurable statistics of app utilization or biosignals recorded by the app

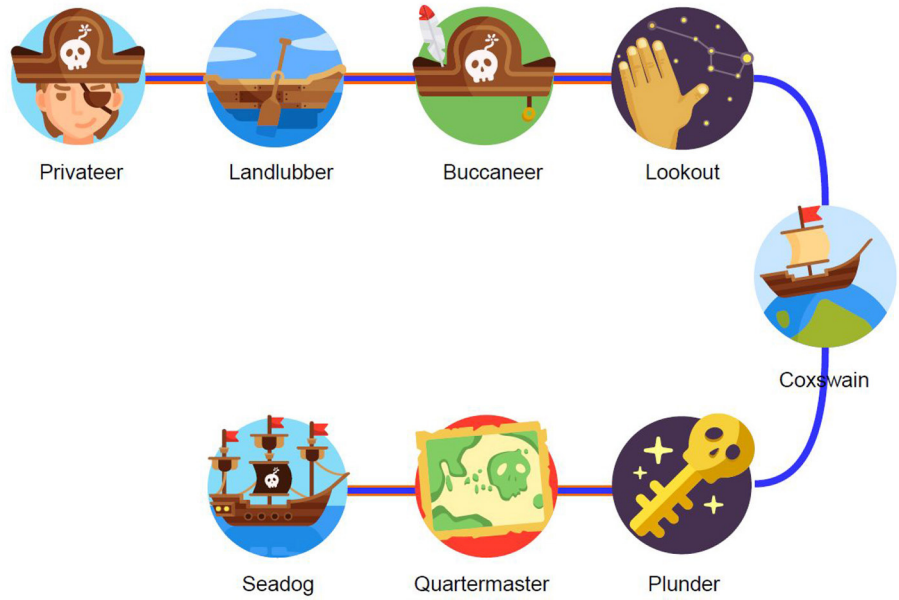


**FIGURE 2 |** Badges can be used to illustrate progression, besides individual achievements.

(e.g., heart rate during physical exercise) or users providing their own self-measurements (e.g., blood pressure measurements compared to those indicated by a GP). By setting concise but understandable aims for the users, gamification helps in focusing on intrinsic motivation and the benefits the application has been designed to provide and removes points and other rewards from the center of attention.

Another helpful instrument toward preventing users from losing interest to the application when rewards become repetitive is that of guidance: in the beginning stages of using a new application, users are guided through the points and badges they collect, since these awards correspond to them using the app properly. However, as mentioned earlier, this may sometimes lead to users *gaming* the system and not focusing on the actual benefits they would receive from the application by using it the way it was designed to; as a result, we need a more elaborate system of providing information about what to do next and on the outcome of a specific action. In health-related applications, users (patients) are at risk of attrition for an additional reason: the exercises suggested to them by the application or their doctor may be difficult to perform or require more effort than they expected (Rotondi et al., 2015), at least in the beginning, before any personalization tools can impact the suggestion process. As a result, they become disappointed in both the application and their outlook, and either neglect their activities or quit the rehabilitation program altogether. In gamified environments, especially in narrative or role-playing games, guidance and support can be manifested through graphical elements (e.g., an arrow or a flashing text message) that indicate which way to go or which option to select next; in an application context, such interface elements might point to specific tools to use next, points remaining to claim a level or badge or notifications that users may have missed. This information scheme becomes more helpful when using avatars or virtual actors as *sidekicks* (Dixit et al., 2018): besides being aesthetically pleasing, avatars help in creating rapport with the users and offer a sense of someone being there to assist them, while users still maintain control about what to do next and which tools or options to select.

The last of the advanced gamification instruments used to go beyond PBL refers mostly to users who have already spent some time and effort with the application and their performance, capabilities and behavior have matured. In order to help users realize their evolution, designers often generate a graphical representation resembling a map or a route, pinpointing the users' achievements and measurements since they started using the app, along with challenges and rewards that lie ahead and the necessary steps to succeed in them. Campbell (Campbell, 2003) refers to this as the "hero's journey", a direct reference to the narrative nature of games and, thus, gamified applications; similar instruments have been used widely in education apps (Bell, 2018) and enterprise systems (Humlung and Haddara, 2019) to supply quantitative and qualitative information about the users' progress and offer positive feedback by treating them as the "hero" of the narrative. In the context of self-help and e-health applications, a hero's journey map may include information about salient events (e.g., when users started specific treatments or were presented with advanced objectives to achieve), measurable quantities such as the time needed to complete a task, how many repetitions they performed at a particular physical exercise or the dates of their consultation sessions with a GP; since long term use of an application may become repetitive, it's important to increase the endogenous

motivation of users, besides rewarding and complimenting their progress, by showing future challenges or application content to be unlocked.

# 4. COACHING

The concept of *coaching* is very popular in the context of self-help or e-health applications, since it caters for personalizing information, suggestions and advice to the users, creating a richer, safer and more effective user experience in the process. Depending on the business model of the application, designers may opt to offer pre-defined sets of instructions or limited choices toward personalization, while for subscription-based apps, GPs and health practitioners may be able to create and edit fine-tuned schedules of exercises and tasks, depending on each user's preferences or individual characteristics. In this section, we will not concentrate on the possible content of a coaching tool, but on presentation and interaction alternatives.

## 4.1. Motivational Messages

Displaying motivational messages during the time users spend on the application is directly related to increasing their confidence, establishing rapport between them and app, and providing direct, personalized feedback (Lee et al., 2013). Depending on the application design and whether personalized feedback is possible or not, these messages may contain uniform content for all users or adapt to their preferences, choices or performance. In the case of uniform messages, the content is related to general information about the purpose of the application and what users can do with it; in the given app context, this information refers to the activities, mental or physical, users have been assigned to perform or how individual tools in the app offer assistance to users achieving their goals (e.g., how meditation can affect blood pressure, combined with changes in life and dietary style and prescribed medication). Besides this, applications may display motivational quotes by recognizable people or scientists: research (Pløhn and Aalberg, 2015) shows that users feel more empathetic to information by people they can recognize or relate to than a simple informatory statement.

An interesting variant of motivational messages with respect to adapting their content and presentation style has to do with motivational attitudes: depending on the user's personality and the actual content of the app, designers may opt to use inciting language or be more austere, as is sometimes the case with personal training applications. User compliance and performance is also used to adapt message content: if users neglect to use the app or show limited interest, the motivational messages may encourage them to be more active and tenacious. If the app still detects a lack of interest from the part of the user, message content may become stricter or suggest alternative exercises and more interesting app tools. In any case, these messages, especially when user compliance and performance are taken into account, can be considered as an advanced gamification instrument, since they offer instant, personalized feedback on how users interact with the app, while transitioning from austere to complimenting language is a clear indication of progress.

## 4.2. Notifications

Notifications and reminders are a motivational tool that is also widely used, given the mobile environments where self-help and e-health apps are usually used and the capability of browser-based applications to display desktop notifications at any time. Notification delivery may take place at Operating System level (e.g., on the lock screen of a mobile device) or in-app, when users log in and start interacting with the application. Given that notification content may sometimes consist of sensitive or personal data, OS-level reminders usually work better in cases where users neglect their scheduled activities or haven't used the application for a few days. As is the case with motivational messages, notification content may include personalized information (e.g., "you haven't used the app for 5 days; time for a quick puzzle") or present general information about how to include app usage in their everyday schedule (e.g., "did you know that you can perform physical exercises even while sitting in your office chair?"). Content may also utilize information from the gamification scheme, showing the necessary steps to achieve the next experience level or be awarded a new badge (Kazhamiakin et al., 2016). In any case, it is extremely important for application designers to allow users to select the frequency and content of notifications, as well as whether they can be displayed at OS-level, since showing too many and too often may lead users to disable or disregard them altogether.

## 4.3. Personalization

In the context of application design, personalization usually refers to users being offered means to adapt or change how information is presented, both in terms of content and aesthetics, and how they can interact with the app. Burley et al. (2020) showed that being able to adapt the application to one's individual style and preferences instills a sense of having control over the app and increases engagement and relevance.

Besides altering the user interface of the application by choosing specific color schemes or displaying selected, relevant tools in a toolbar, personalization usually refers to the user's avatar, an iconic rendering which represents the user in the app context (Heffernan et al., 2016). Avatar-based representation (**Figure 3**) is also an artifact found in digital games and appears to increase user empathy to the app, which in turn increases confidence and engagement (Mavrikis et al., 2019; Sebri and Savioni, 2020). In addition, the user's avatar can be used to represent them in the hero's journey mentioned earlier and visualize their current affective or cognitive state: e.g., a smiling face and energetic avatar gestures can be used to represent a user who advances through the app quickly and complies completely with the instructions given to them (Lyles et al., 2017). Avatars are also widely used to implement a rewards-based gamification scheme, where users receive virtual goods (for instance, coins or experience points) as a token of appreciation of their effort and


**FIGURE 3 |** The ability to personalize their avatar has been shown to increase rapport in users (Mavrikis et al., 2019).

progress and "spend" them to buy clothes or accessories for their avatar (Schmidt-Kraepelin et al., 2020).

# 5. USER ANALYSIS

## 5.1. Selection of Activities

The core of the MediLudus application is a Health-based Recommendation System (HRS - Sahoo et al., 2019), i.e., a system which suggests specific activities to patients, aiming to maintain and improve their mental and physical health. In addition, a HRS provides valuable insights to medical practitioners, based on long-term sensor data or emerging events, e.g., a detected fall, a spike in one of the measurements, or reduction of patient adherence, so that they can adapt the plan of activities assigned to each patient or consult with them directly. While the selection of physical and mental activities is the responsibility of the medical practitioners, our application implements some of the gameful concepts described above so as to achieve increased motivation, *via* rewards and comparisons with other users, and instant feedback to patients, *via* the badges/points system and the user journey.

Our design is based on 3 distinct, but inter-related concepts, Challenges, Plans, and Targets. A *Challenge* is an activity with a pre-defined duration (e.g., a week) and specific *Targets* which comprise a *Plan* (e.g., "walk 5K steps every day for week"); it may refer to a particular aspect of the patient's experience (i.e., Physical, Diet, Mental, Care, or App usage) and is rewarded with a specific badge. Each patient may take part in different challenges at the same time, while multiple patients may share a specific challenge as well. A challenge that refers to Diet typically affects the amount of protein, carbohydrate or lipid intake and the amount or time between meals; all related information is input to the app by the users. Physical activity challenges may refer to walking a particular number of steps in a day or within the timeframe of the challenge, or earning "Heart rate points" associated with high-intensity or anaerobic exercises. Some of these challenges may be more forgiving, especially for newly-joined patients: for example, a weekly walking challenge may allow patients to miss the daily target for a single day and still succeed in the challenge. This allows patients to receive the benefits associated with the objective of the challenge and receive the motivating rewards to keep their interest and self-esteem intact. Challenges labeled as "Mental" refer to using the brain games included in the app and their Targets may refer to in-game progress (e.g., "achieve Level 5 in the *Parity* game), number of game sessions or duration of gameplay ("Play Sudoky for a total of 90 minutes over a week"). Finally, *Care* challenges refer to social interaction, e.g., going out for a walk every day or calling a friend or relative, while *App* challenges refer to using the application consistently (time spent on the app, pages visited, number of notifications read and responded to, etc.).

## 5.2. Targeted Users

Overall, our project focuses on sustaining the ability for independent living for adults in need of medical care and observation, regardless of their age. This refers to three different groups of possible users of the application: the *end users* or patients, whose physical and mental condition we aim to stabilize and improve, the *counselors*, i.e., medical practitioners or physiotherapists who define an activity schedule for the end users and monitor their progress to make adjustments, and *supporting users* who may influence the adherence and social behavior of end users.

In the case of elderly end users or patients, studies (e.g., Elward and Larson, 1992 or Fenicchia et al., 2004) have shown that a targeted strategy of daily activity and physical exercise may drastically reduce the risk to develop conditions related to mental activity, such as dementia, or physical condition, e.g,, diabetes or atrial fibrillation. In addition, individuals close to retirement (62–70 years old) face changes in lifestyle, socialization, income, and autonomy, which may influence their well-being. Although empirical evidence (Barnett et al., 2012) is inconclusive as to the actual impact of increased physical activity during that stage, the theory of Continuity (Kim and Moen, 2002) suggests that people prefer to maintain their social habits and activities past their retirement; in our case, this includes mild exercise or physical activity, which can improve their respiratory capacity even with 2–3 sessions per week. For younger adults, our focus is mostly on users in need of rehabilitation after an unexpected incident or injury, such as a stroke or spinal injury. In these cases, a counselor is assigned to each patient and prescribes a schedule of activities which repeat for a given time period. Besides listing those activities and helping the patient perform them, our application assists monitoring of their physical state through sensors embedded in a tablet (Hammer et al., 2015) or smart watch, reporting sleep duration and quality, total steps when walking or jogging, speed of walking, etc.

The second group of users (counselors) must be provided with tools to monitor how patients comply with their prescribed schedule of activities, evaluate data and major events collected through the sensors, and communicate with the patients or caregivers when necessary. Medical practitioners constitute a

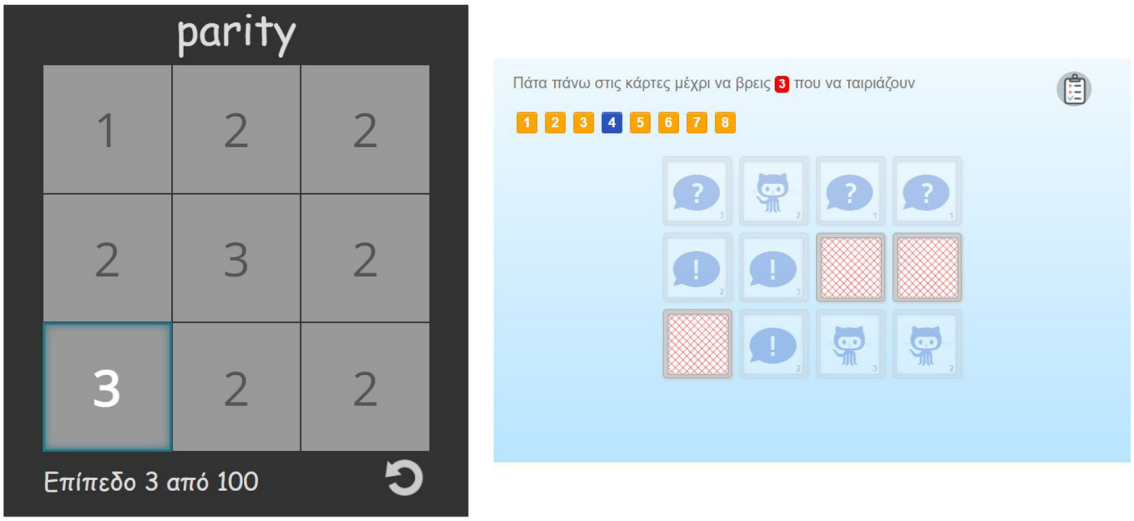


**FIGURE 4 |** Examples of game activities in MediLudus.

major part of this group, since they are primarily the ones to prescribe the schedule of activities: choosing from the available physical or mental exercises and games (cf. **Figure 4** for two examples of available mental games), deciding the programme duration in days or week, setting performance targets for each activity and the number of repetitions. They must also take action when the readings from the sensors are unusual or alarming and present the need for an intervention. Physical therapists can also use the application to choose exergaming (cf. Gourgari et al., 2013 or Street et al., 2017) activities for patients and receive information about the patients' compliance and success with the aims of each game. Finally, supporting users (relatives, caregivers or close social contacts, as defined by patients) are also included in the stakeholder list, since they may support patients in executing their everyday routine and persevering when they encounter difficulties. Privacy is an important issue for this user group, since the actual physiological signals should not be shared with them; instead, they can be informed about the patient's progress through a dedicated community tool and encourage or support them either in person or through social media-like reactions.

## 5.3. User Journey

User journeys (Taki et al., 2017) constitute a powerful tool when it comes to identifying the different phases of user experience, from onboarding to experienced users, and mapping the expectations they may have from interacting with the application. This process can be instrumental in predicting "choke points" and providing ample and timely support to users, when they need it; user journeys can also help designers anticipate patterns which indicate high probability of user churn, and utilize reminders, notifications or inducement strategies to keep users interested in the app. **Figure 5** presents a typical user journey for the MediLudus app, which we used to elaborate on the gamification and feedback tools.

The different phases of this user journey were defined after consultation with representatives from all groups of stakeholders and extensive literature review. According to this, we expect users (patients) to show great interest in the application in the beginning stages (onboarding), mainly thanks to its novelty and the sense of support and care offered to them. As they become acquainted with the application tools and options, and begin to execute the prescribed activities, we expect that their interest will decrease, due to the need for daily compliance and the learning curve associated with trying new tasks. This makes sense, since many of our predicted users have not engaged in physical activity for a long time, if at all. In order to decrease negative feelings, we employ gamification tools, enabling patients to compare their performance and progress with other users with similar profiles; this will illustrate that they are not the only ones who struggle, as many patients find it difficult to adjust when first using a new application. In addition, by comparing themselves with others based on performance and compliance (whether they follow their prescribed routine closely or not), patients receive feedback on their progress, which motivates them to persist through this difficult phase. This progress will be signified by badge rewards, which users can share with their contacts in social media, further improving their sense of value and confidence.

The next predicted choke point is anticipated when sense of novelty from the offered activities and the first badge rewards is reduced. As a result, patients lose the internal motivation to comply with the schedule assigned to them and tend to neglect the daily use of the application. To prevent this, the app uses notifications to remind patients to integrate the suggested activities to their daily routine and identifies specific tasks to quickly improve the patients' performance, offering them elaborate guidance and creating the sense of progress from a novice user to an advanced one.

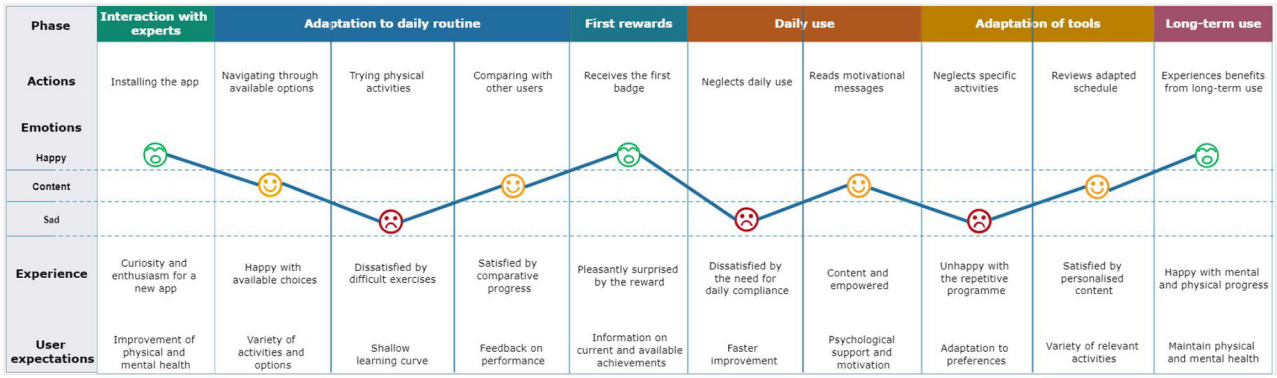


**FIGURE 5 |** Predicted user journey for the MediLudus app.

**TABLE 1 |** Engagement measurements.

| Indicator | Definition | Measurement |
|---|---|---|
| Entertaining | Subjective measurement of perceived entertainment and engagement using a 5-point Likert scale | 1-boring, 5-very entertaining, will use very often |
| Interesting | Subjective measurement of perceived interest and engagement using a 5-point Likert scale | 1-not at all interesting, 5-very interesting, will use very often |
| Adaptive | Subjective measurement of content and presentation adaptivity tools perceived using a 5-point Likert scale | 1-no adaptivity, 5-fully adaptive, all choices are recorded |
| Interactive | Subjective measurement of feedback toward user input and choices using a 5-point Likert scale | 1-no interaction or feedback, 5-high level of feedback, variety of possible choices |
| Focused on target group | Subjective measurement of content clarity and usability for the selected target group using a 5-point Likert scale | 1-content and presentation are vague, 5-content and presentation are targeted and relevant |

**TABLE 2 |** Functionality measurements.

| Indicator | Definition | Measurement |
|---|---|---|
| Performance | Subjective measurement of perceived correctness and clarity of tools and menus using a 5-point Likert scale | 1-non-functional, incorrect, 5-performs quickly and correctly, easy to estimate time to complete a task |
| Ease of use | Subjective measurement of perceived learning curve and clarity of interface and instructions using a 5-point Likert scale | 1-lack of instructions, unclear interface, 5-simple and elaborate interface, easy to onboard |
| Navigation | Subjective measurement of ease and logic between different tools and application screens using a 5-point Likert scale | 1-no logical connection between screens, difficult navigation, 5-simple and clear navigation, provision of shortcuts |
| Automation | Subjective measurement of provision and coherence of interaction automation, such as taps, swipes, etc, using a 5-point Likert scale | 1-no automation or incoherent, 5-high level of coherent and reliable automations |

In the third stage of application use, patients have already figured out the benefits from its use and are following their daily activities quite closely. Rewards are mostly a chance for competition or comparison with other users, with the patients' position in a leaderboard acting as a motivator for improvement and compliance. Going over the same activities for a long period may introduce fatigue or boredom to the users, possibly resulting in them neglecting their routine. To avoid this, the app employs the personalization tools which adjust the patients' schedule to their individual preferences and needs, focusing on activities which may attract their interest, while maintaining their physical and mental health. Adaptation also refers to the performance and repetition targets for each activity, further adjusting the difficulty level for them and offering users extra motivation to comply. In this manner, the application relies more on the patients' intrinsic motivation, founded on their self-esteem and perceived sense of progress (since this is a tool offered to advanced and high-performing users), rather than extrinsic rewards, such as badges or reminders.

**TABLE 3 |** Information measurements.

| Indicator | Definition | Measurement |
|---|---|---|
| Clarity of description | Subjective measurement of the clarity and correctness of the description of the application in App/Play Store using a 5-point Likert scale | 1-deceiving, lacks information, 5-extremely accurate |
| Objectives | Subjective measurement of whether objectives are clear, measurable and achievable using a 5-point Likert scale | 1-objectives are not mentioned, impossible to achieve, 5-well-defined, measurable objectives, possible to achieve |
| Quality of information | Subjective measurement of the content, its clarity and correctness, and relevance to app aims using a 5-point Likert scale | 1-incorrect/ incoherent/irrelevant content, 5-relevant, appropriate and correct content |
| Quantity of information | Subjective measurement of perceived quantity and coverage of application content using a 5-point Likert scale | 1-too little or too much content, 5-relevant and well-defined, links to additional content |
| Visual information | Subjective measurement of concept elaboration using images, graphs or videos using a 5-point Likert scale | 1-unclear or incorrect content, 5-high level of clarity |
| Reliability | Subjective measurement of how reliable the presented information is using a 5-point Likert scale | 1-sources are mentioned but are not trusted (e.g., conflict of interest), 5-sources are publicly funded scientific organizations |

**TABLE 4 |** Interaction measurements.

| Indicator | Definition | Measurement |
|---|---|---|
| Click-depth | Number of page visits in 1 day | Number of sessions with visits $\geq$ 2 pages/Total number of sessions |
| Loyalty | Frequency of application access from onboarding | 1-(1/visits per month) |
| Interaction | Number of notifications to which the user responded | Notifications to which the user responded/Total notifications |
| Recency | Time between 2 successive visits | 1/mean time between visits over a month |
| Feedback | Subjective measurement of user satisfaction | Number of positive answers/Total number of questions |

## 5.4. Key Performance Indicators

In this section, we describe measurable indicators monitored during application testing. Most of these are subjective and common to most mobile applications, but elaborated for the context of medical use and self-help (Taki et al., 2017). These indicators are useful during the early evaluation phase, when end users and stakeholders have the chance to interact with the application, its tools and content, and their experience is fed back to the design and development team for possible updates. The KPIs described in the following are based on the Mobile App Rating Scale (MARS) proposed by Stoyanov et al. (2015): in this work, a number of research articles related to mobile applications and their evaluation were assessed, along with applications available on the Apple iTunes store, focusing on well-being, anxiety, stress, depression and CBT, resulting in a multi-dimensional measure of engagement, functionality, aesthetics, and information quality, as well as subjective app quality. MARS was validated for self-help apps by Stoyanov et al. (2015), for contexts related to emerging and ambulatory events by Creber et al. (2016) and apps related to diet and physical activity by Schoeppe et al. (2017).

### 5.4.1. Engagement

This indicator (cf. **Table 1**) measures how successful the application is in terms of offering a pleasant and rewarding user experience.

### 5.4.2. Functionality

This indicator (cf. **Table 2**) measures how usable the application is and whether there is a need to redesign the user interface. This indicator, as well as parts of the *Information* indicator, are related to the System Usability Scale (SUS) tool, suggested by Brooke (1996), as well as the Technology Acceptance Model (TAM), used by Yusoff et al. (2010) in the context of serious games; in our work, we opted for operationalizing the functionality of both tests using simplified questionnaires, as well as automated tests, where possible (e.g., to estimate successful vs. unsuccessful attempts or the time it takes for a task to be completed).

### 5.4.3. Information Measurements

This indicator (cf. **Table 3**) measures whether the information mentioned in the application is accurate and clear, and the objectives the user has to achieve are relevant.

### 5.4.4. Interaction

This indicator (cf. **Table 4**) measures how users respond to application prompts and how the application provides feedback to users.

# 6. CONCLUSIONS

In this article, we described the different concepts related to designing a mobile application to assist patients in rehabilitation. We focused mainly on facilitating the proper design of activity schedules for each patient and improving their experience by employing tools such as gameful design and gamification, personalization, and coaching. These tools can assist in facilitating rapport with the application, maintain the patients'

interest and engagement in the long run, and increase the positive effects of physical and mental exercise in the process. Even though this is beyond the scope of our application, which focuses on rehabilitation and people in need of observation or mild treatment, general-purpose e-health applications may benefit from this gameful design approach, especially when it comes to designing and implementing a narrative structure and offering guidance and support whenever users fail to comply to their scheduled exercises. Since the onset of the current pandemic, when many people resorted to exercising alone, even at home, finding the discipline to go through a fitness program has been found to be more challenging than expected; as a result, an exercise recommendation application that suggests *personalized* training schedules and adapts to the users' *affective state* can be much more effective than a one-size-fits-all solution. In this work, we also described a number of subjective, yet measurable indicators to help us measure that user experience during the early evaluation process, leaving the design team ample time to integrate any findings and suggestions. Receiving feedback from the users during app usage is important, not only to correct any design errors in future updates, but mainly to adapt their experience using the approaches presented here.

## DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

## AUTHOR CONTRIBUTIONS

KK was the lead in the gamification and gameful design work. IM in design principles related to medical needs. AM, CP, and AP in development and deployment and evaluation concepts. All authors contributed to the writing-up of this article and the design of the application. All authors contributed to the article and approved the submitted version.

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