Gamification Design Framework for Mobile Health: Designing a Home-Based Self-management Programme for Patients with Chronic Heart Failure

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Abstract. Gamification is the design nexus between psychology and technology; thus, the ensemble of game design concepts and mobile health is promising for a far-reaching impact in public health. This paper presents a gamification design framework for mobile health as a unified, structured representation of activity systems aiming towards better health-related outcomes. It provides a valuable guideline for researchers and designers to model and gamify complex interventions into mobile health design with four steps: (i) defining activity systems, (ii) modelling, (iii) transforming, and (iv) designing. The framework is demonstrated for gamification of a home-based self-management programme for patients with chronic heart failure.

Keywords: Gamification · Design framework · Mobile health
Activity theory · Self-management · Chronic disease · Heart failure

1 Introduction

Gamification has increasingly become a hot topic over the past few years. The adaptation of game design concepts in non-gaming contexts is a new, promising paradigm for reshaping user engagement [1, 2]. Gamification design has been studied as useful in many areas such as e-commerce [3], education [4, 5], and health care [6]. It is the combination of psychology and technology point towards business objectives [7]; however, the role of technology has been significantly evolved in gamification. With unique technological capabilities, mobile health is the next suitable wave of technologies for modifying patient engagement and activities, thereby transforming gamification design in health care. Hence, the focal research question of this paper is: "how to gamify mobile health to address public health problems?"

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Chronic Heart Failure (CHF) has become a major problem of public health with its high and increasing prevalence worldwide [8]. The risk of CHF increases sharply along with patients' age and gender [9]. It is estimated that over 30% of individuals who are aged 55 and above will likely develop heart failure during the remaining course of their life [10]. CHF occurs as a clinical endpoint of many cardiovascular disorders, especially those that impair cardiac function or strain the cardiac workload [11]. It has become a heavy burden of healthcare systems; hence, self-management has been long recommended as an integral component of treatment for patients with CHF [12]. Nevertheless, many older patients who would potentially benefit from self-management interventions do not participate them [13]; moreover, a past study has shown that feelings of hopeless and powerlessness are common among them [14]. Therefore, it is imperative to explore the ensemble of gamification and mobile health for a simple, convenient means of self-management with a right amount of motivational affordances. It has capabilities to empower patients with continuous psychological and social support from care givers, family members, and friends.

This study investigates gamification design as a holistic structure of activity systems. We propose a gamification design framework for mobile health with four steps: (i) defining activity systems, (ii) modelling, (iii) transforming, and (iv) designing.

This paper contributes to the cumulative theoretical development of gamification design and mobile health in several folds. The proposed design framework provides a structured procedure for researchers and designers to model and to gamify complex interventions into mobile health design. We also present a gamification of home-based self-management programme for patients with CHF.

The structure of the paper is as follows. Firstly, we discuss the background of our research in the next section. Secondly, we describe a gamification design framework for mobile health in great details in the Sect. 3. And then, the paper demonstrates the use of the design framework for a home-based heart failure self-management programme. Lastly, we concluded our paper with findings and contributions of the research in the final section.

2 Background

2.1 Gamification Design

Gamification refers to the use of game design elements in non-gaming [1]. Such design elements are motivational affordance contexts for engagement purposes aim towards specific goals [15]. Recent studies have shown positive, psychological effects of gamification in many areas such as e-commerce [3], education [4, 5], and health care [6]. Table 1 summarizes the typical game design elements, which are adapted from Hamari et al. (2014) [16].

The design process of gamification is about how to incorporate various gamification elements into different contexts [17]. Several gamification design framework have been developed as guidelines for researchers and designers in general and business-specific domains [15]. Werbach and Hunter (2012) proposed the most popular design framework in Six Steps to Gamification (6D) [18]. The 6D framework consists

Table 1. Typical game design elements (Adapted from Hamari et al. 2014)

Game design element	Description
Reward	An obtainable object in recognition of participation, efforts, or performance such as monetary incentive, status, or self-development benefit
Point	Users earn points by joining the activity
Clear goal	The object of users' efforts to achieve in the activity
Leaderboard	A visual board for displaying and comparing user's performance with others
Achievement/Badge	Users can be awarded with virtual badges or recognitions, or merits for participation and performance
Level/Progress/Feedback	An indicator that provides reflections to users on where they are in the activity
Story/Theme	A mechanic that draws the users' interest into the activity. They provide guidance for users to move forward
Challenge	A pre-defined task that motivates users to action
Loop	An engagement mechanic that integrates positive reinforcement into repeated activities to keep users engaged

of six steps: (1) define business objectives, (2) delineate target behaviors, (3) describe your players, (4) devise activity cycles, (5) don't forget the fun!, and (6) deploy the appropriate tools. In a similar vein, the GAME framework developed by Marczewski (2012) suggests breaking the design process into two phases: planning and designing, to derive a solution in the gamification context [19]. In additions, a number of business-specific frameworks for designing gamification has been introduced to activate game elements and techniques in complex business processes [20, 21]. Nonetheless, there is a dearth of a structured framework for gamification design that is capable of modelling and translating activities in different contexts into practical design. Furthermore, new technologies are constantly reshaping human engagement; thus, gamification is not without considering the enabling role of technologies.

2.2 Mobile Health

The growth spur of mobile technologies has paved the path for new health interventions, "mobile health" or "mHealth" [22]. It is broadly defined as "the use of mobile computing and communication technologies in health care and public health" [23] which is capable of delivering health services to a huge number of people. Mobile health technologies have transformed a variety of health-related activities such as disease management and prevention [24–28], care surveillance [29–31] and instructional interventions [26, 32].

With the significant advantages of usability and mobility, mobile health apps are the next suitable wave of interventions for enhancing healthcare [33, 34]. They offer a wide range of capabilities from displaying and reporting to real-time sensing and social media sharing. Table 2 shows a list of common mobile health capabilities, which are typically used in combination.

Table 2. Common mobile health capabilities

Capability	Description
Interactive touch	A smartphone is typically equipped with a touch screen which allows users to control through simple or multi-touch gestures
Connectivity and social media	Mobile and internet connectivity allow smartphone users to maintain constant connections with social support actors or care givers
Displaying/Reporting/Visualization	Rich displaying and reporting contents such as websites, images, and videos provide multiple means for health intervention delivery
Wireless health sensing and monitoring	Wireless technologies such as Bluetooth, Near-Field Communication (NFC), and Wi-Fi allow users to connect medical devices for continuous sensing and monitoring
Push notification/Reminder	A mechanism to bring information to smartphone users for their attention

Mobile health interventions in their current form, however, are limited in psychological capabilities, which possibly render their effects temporary on health-related behaviors [35]. Hence, gamification of mobile health is a promising paradigm towards transforming patients' engagement for better outcomes.

3 Gamification Design Framework for Mobile Health

Gamification is defined by the Oxford dictionary as "the application of typical elements of game playing (e.g. point scoring, competition with others, rules of play) to other areas of activity" [36]. The core of gamification leverages on the principles of game design theory [15]; however, the design process of gamification is conceptually distinguished from game design, which is typically for entertainment purposes. The main purpose of gamification design is to enhance activities in different contexts towards specific, shared outcomes. Hence, the design process does not only entail the use of game design elements or techniques, but also revolves around human activities with the use of technology. In this paper, gamification design is viewed as the investigation of activity systems based on multiple factors such as tools, controls, contexts and communications. Exploring activities as dynamic phenomena is the key to obtaining extensive understanding of the design process, and supporting expressive human interactions in gamification.

The engagement between people and technology develops and shares meanings and objectives in activity systems. Mobile health, in which smartphones are interactive agents, has continuingly transformed human-technology interactions in an unprecedented way. It is necessary for the design process to capture the operationalization of the dialectal relationship between people and mobile technology. Therefore, a design framework for gamification of mobile health is proposed as a unified structure of

activity systems, which encompasses various aspects of human-technology interactions, game design elements, and mobile health capabilities. It consists multiple steps for researchers and designers to extend the framework structure into practical design artefacts. Four steps in the gamification design framework are: (1) defining activity systems, (2) modelling, (3) transforming, and (4) designing.

Step 1: Defining Activity Systems

The first step of the gamification process is to define the activity systems in mobile health. It involves decomposition of the activity systems into several components for analysis and design from both psychological and technological perspectives. Grounded in the activity theory [37], we propose a holistic structure of activity systems for gamification of mobile health based on our previous thereotical framework [27]. It consists of seven components: (1) outcome, (2) subject, (3) object, (4) tool, (5) context, (6) control, and (7) communication, as shown in Fig. 1,

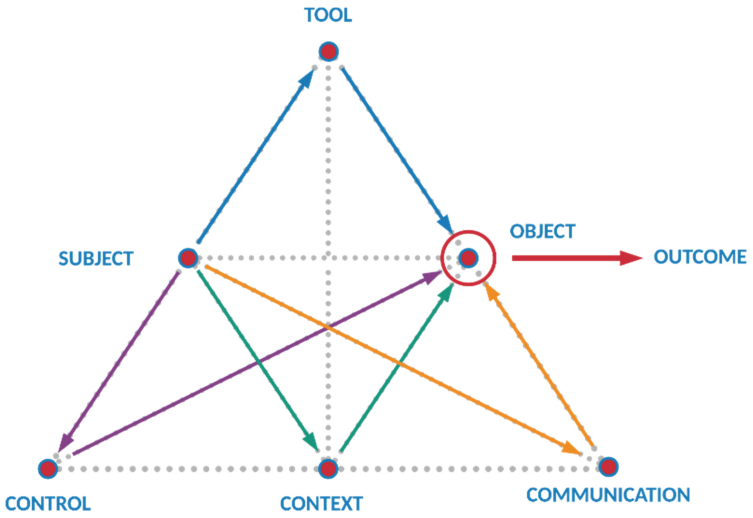

Fig. 1. Activity systems for gamification of mobile health

(1) *Outcome*. A well-developed understanding of the outcome in activities is vital for the gamification design process. In mobile health, improvements in knowledge and skills, as well as health-related behaviors are commonly defined as the collective outcome.
(2) *Subject.* The "subject" component depicts both individual and social nature of the activity. The stakeholders of health interventions are patients and psychological/social support actors.
(3) *Object*. The "object" or "objective" component reflects the purposes of activities that allow the manipulation of subjects' actions. In mobile health, the object is typically a collection of health-related behaviours and outcomes.

(4) *Tool*. The "tool" component shows the mediation aspects where in-teractions between subjects are not direct, but mediated through the use of technological capabilities and instructional materials. Mobile health apps have excellent capabilities as discussed in Sect. 2.2 to facilitate health interventions.
(5) *Control*. The "control" component refers to how activities are conducted and managed based on technological and psychological elements. Game design elements such as stories, clear goals, or challenges are some examples of gamification controls.
(6) *Context*. The "context" component highlights the situation and environment, in which the subjects perform activities. For instance, locational, temporal, and social constraints have been removed in mobile health; thus, it enables subjects to participate in activities anywhere anytime. Social media is also a technological context that motivates subjects to action.
(7) *Communication*. The "communication" component refers to how subjects engage and what are their role structure in the activity systems. The use of mobile technologies empowers the subjects with different forms of communication such as one-to-one or group communication.

In this step, it is important to have well-defined activity systems and a comprehensive list of activities as inputs of the gamification design process.

Step 2. Modelling
The modelling step consists of two structured tasks: (i) modelling each and every activity listed in the previous step, and (ii) identifying gamification design components. They are described as the following.

(i) *Developing activity models*. This objective of this task is to describe the dynamic aspects of activity systems. In this paper, we propose the use of Unified Modelling Language (UML) [38] to depict the flow from one action to another. Activity diagrams are graphical representations of such flow for researchers and designers to investigate the activity systems.
(ii) *Identifying gamification design components.* The second task of this step is to explore the mediating role of different components in our design framework including tool, control, context, and communication. We suggest the use of Mwanza's techniques [39] to generate possibile gamification opportunities. In Fig. 1, the arrows run from the subject through a mediating component towards the object, in which gamification opportunities can be recognized in the activity systems. There are four questions to identify gamification elements: what tool can help the subject to achieve the objective? what control can affect the subject to transform the object? what context can influence the subject to reach the object? or what communication can change the way the subject reach the object?

This step develops activity descriptions with a list of gamification design components.

Step 3. Transforming
Psychological/social support actors, including doctors, nurses, care givers, family members, or friends, play a critical role to intrigue patients to participate in health

interventions. Based on activity diagrams in the step 2, the activities can be transformed by supplementing or substituting such actor with technological subject in this step. In the former scenario, smartphones can be explored as an ancillary resource for enhancing patient engagement; while, the latter scenario portrays mobile devices as the primary actor, as known as mobile support actor. Hence, the activity diagrams and the list of gamification design components can be revised with the new role of mobile support actors. There are additional questions to describe gamification and design mechanics: how does tool help the subject to achieve the objective? how does control affect the subject to transform the object? how does context influence the subject to reach the object? or how does communication change the way the subject reach the object?

For example, how do wireless monitoring devices assist patients to improve weight management? Or how does reward points motivate patients to participate in a health exercises? Or how do displaying and visualization capabilities enable patients to recognize symptoms?

In additions, the inter-connections among tool, control, context, and communication can also be investigated to enhance the gamification models.

Step 4. Designing

The objective of the designing step is to translate gamification models in to a practical design product. In mobile health, mobile apps are commonly referred as the end product of the design and development process. Hence, this step involves the creative design of user interfaces of mobile apps for touch-sensitive display on smartphones. We suggest the use of UML-based use case diagrams and use case descriptions to describe design concepts. These concepts serve as the basis for user interface/experience (UI/UX) designers to create mobile user interfaces.

This gamification design framework presents a unified, structured guideline for game designers, UX/UI designers, researchers, and theorists to gamify mobile health interventions. The use of the framework in a health-specific application is illustrated in the next section.

4 Designing Home-Based Heart Failure Self-management Programme

This paper discusses a home-based self-management programme for patients with chronic heart failure (CHF). The primary aims of the programme are to increase self-care behaviors, self-efficacy, and social support, as well as, improving health-related quality of life. It is imperative to equip CHF patients and family members/care givers with knowledge to improving heart failure self-management skills. In a long run, the programme is promising for a far-reaching impact, extending beyond the individual's physical and financial costs and affecting society at large. With integration of mobile health technologies, a larger proportion of the patients with CHF would be able to receive the rehabilitation in a more acceptable, easily accessible and fun way, especially for older patients. Hence, gamification design of the programme has been deliberated at the very beginning at the study.

The design process has spanned over six months by a group with more than ten members from many disciplines including clinicians, researchers, designers, and software developers. We employed the proposed gamification design framework as an effective means for brainstorming and communicating among team members to reach the final, practical design for the mobile-based self-management intervention. The process of gamification design is clearly documented in great details in subsequent sections.

4.1 Identifying Activity Systems

Self-care management is an integral component of heart failure treatment [12]; thus, it is critical to motivate patients, family members, and care givers to mandate tailored interventions on self-care maintenance and management with suitable practical guidelines and activities. Therefore, the home-based heart failure self-management programme is developed with several objectives in accordance to international practical recommendations for patients with CHF [40]. Figure 2 summarizes the objects of the activity systems under the programs towards achieving the primary aims.

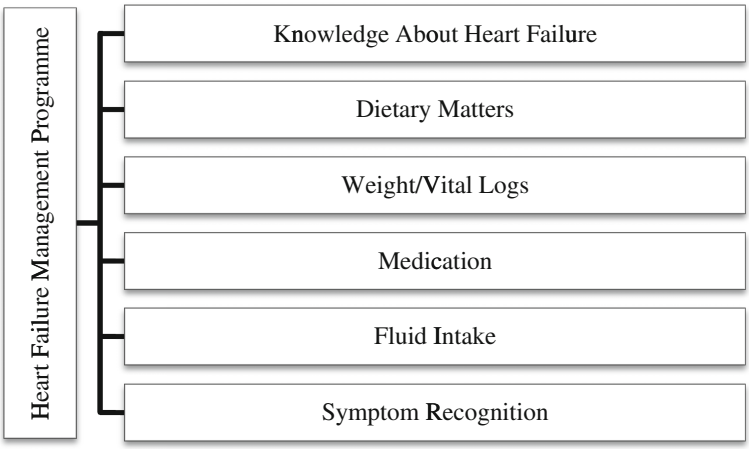

Fig. 2. The home-based heart failure self-management programme

(1) *Knowledge About Heart Failure.* The set of education activities for improving patients' knowledge and skills for several areas: (i) understanding heart failure, (ii), managing heart failure, and (iii) living with heart failure.
(2) *Dietary Matters*. Enhancing patients' self-care behaviors in selecting healthy food, and taking low salt diet. It is advisable for patients to have 2000 mg sodium nutrition plan per day.
(3) *Weight/Vital Logs*. Monitoring of lean weight, blood pressures, and heart rates on regular basis. It is critical for patients to respond to a sudden unexpected weight gain of more than 2 kg in 3 days.

(4) *Medication*. Understanding of medications and their uses/side-effects. The patients are instructed to take medications timely in accordance to doctors' recommendations.
(5) *Fluid Intake*. Focusing on optimal fluid management for patients with heart failure which is recommended at 1500 mL of fluid intake over 24 h. Participants can join interactive activities to keep track of their fluid consumption per day.
(6) *Symptom Recognition*. The patients are advocated to detect and recognize warning symptoms quickly to take appropriate action.

The activity systems of the home-based heart failure self-management programme, hence, are described in Table 3.

Table 3. Activity systems of the programme for CHF patients

Component	Elements
Outcome	• Self-care behaviors, self-efficacy, social support, and health-related quality of life
Subject	• Patients, Psychological/social support actors (e.g., family members, friends, caregivers, or clinicians)
Object	• Knowledge about heart failure, dietary matters, weight/vital logs, medication, fluid intake, symptom recognition
Tool	• Instructional materials • Mobile health capabilities: interactive touch, connectivity and social media, displaying/reporting/visualization, wireless health sensing and monitoring, push notification/reminder
Control	• Guidelines, protocols and recommendations • Gamification controls: reward, point, clear goal, leaderboard, achievement/badge, level/progress/feedback, story/theme, challenge, loop
Context	• Virtual communities: social media or health communities • Location-based • Time-based
Communication	• Face-to-face, one-to-one, group discussion, role structures

The activity systems consist of several high-level activities as below: (1) transferring knowledge and skills, (2) nutrition planning, (3) weight and vital signs monitoring, (4) medication management, (5) fluid management, and (6) symptom recognition.

4.2 Modelling

For each high-level activity, we use UML activity diagrams to model the activity with the structured flow of actions. This step enables us to identify the opportunities for gamification design. For brevity, we use the "nutrition planning" activity as the example of the modelling step; because it has been identified as one of complex activities in the programme. The nutrition planning activity requires patients' knowledge and patience to learn and manage their daily diets to avoid excessive salt intake. Figure 3 depicts the UML activity diagram of the nutrition planning.

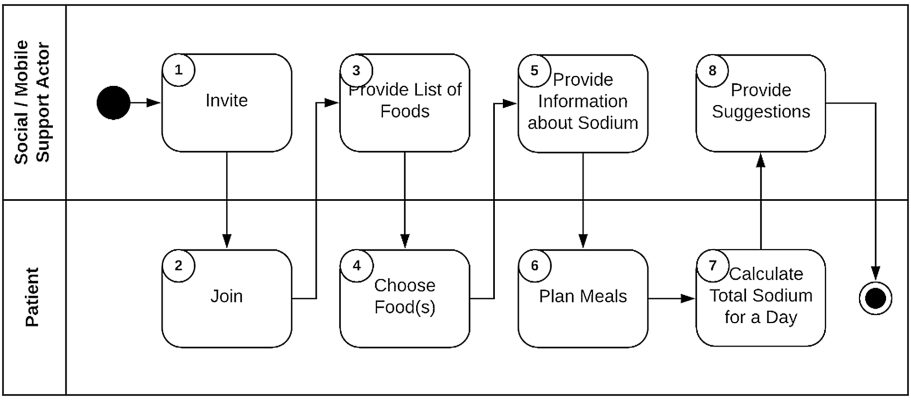

Fig. 3. The UML activity diagram of nutrition planning

There are eight (8) sub-activities in the nutrition planning activity. For each sub-activity, the questioning technique is employed to develop the activity descriptions as shown in Table 4.

Table 4. Gamification design elements in nutrition planning

Sub-activity	Elements
1. Invite	• Tool: push notifications/reminders • Control: challenge • Context: time-based
2. Join	• Control: point
3. Provide list of foods	• Tool: displaying & visualization, instructional materials
4. Choose food(s)	• Tool: interactive touch • Control: clear goal
5. Provide information on sodium	• Tool: displaying & visualization • Control: achievement
6. Plan meal	• Tool: interactive touch, and reporting • Control: achievement, reward • Context: time-based
7. Calculate total sodium	• Tool: displaying & visualization • Control: challenge, loop, progress
8. Provide suggestions	• Tool: displaying & visualization, connectivity and social media • Control: reward, level/progress, point, feedback • Context: social media

4.3 Transforming

In this step, the activity systems are transformed into mobile health by introducing the mobile support actor. Each component of the activity systems is investigated through a structured information gathering technique to determine how it can mediate the subject to achieve the objective. The interactions between people and technology are documented in use case descriptions, which are not included in this paper for brevity.

In Fig. 4, the design concepts for nutrition planning are illustrated in the left panel. There are several elements designed based mobile health capabilities and game design elements: (i) an information box for providing list of foods, selecting food, and providing information; (ii) time-based boxes for planning different meals of the day, (iii) an information box for a total sodium of the day, and (iv) an information box for providing suggestion and feedback.

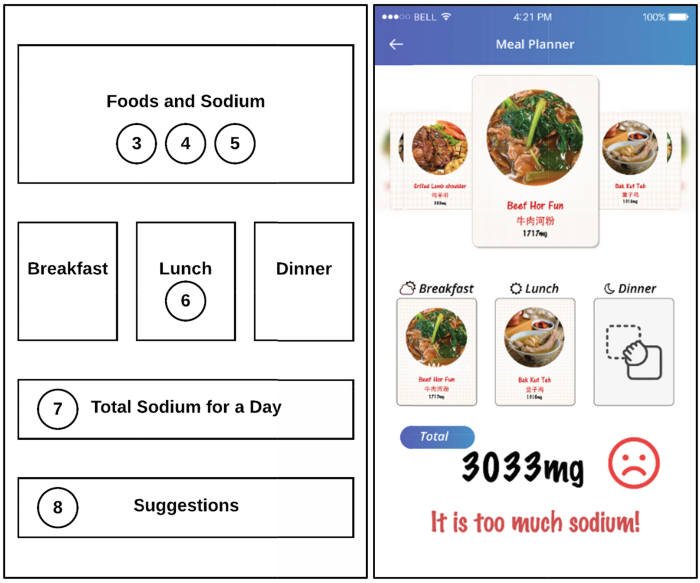

Fig. 4. Design concepts for nutrition planning

The deliverables of the transforming step are the revised activity diagrams, the updated use case descriptions, and the design concepts in words or graphical representations.

4.4 Designing

The last step of the gamification design framework is to translate the design concepts into practical user interfaces. This step heavily involves creative work from UI/UX designers to follow the information architecture and flow concepts for each activity. Mobile and design constraints are also considered to produce the final design of mobile health apps.

In the home-based heart failure self-management programme, several prototypes are developed iteratively and are improved over time with the updates of design concepts. The final design prototype is reviewed by a group of clinical experts and patients. It encompasses a number of gamification design elements and mobile health capabilities. The following highlights the key features of our mobile apps for patients with CHF. In Fig. 4, the final design of nutrition planning is manifested based on the design concepts in the right panel.

Rewards. The source of motivational affordances is embedded in the gist of the mobile app as shown in Fig. 5. It provides the gamification backbone for every activity participated by the users in the activity systems. An intelligent point system is introduced with different numbers of points awarded for participation and performance in different activities. For instance, users earn more points for adherence to medication management than following educational activities. In this study, the rewards feature is linked with monetary incentives for weekly self-care behaviors.

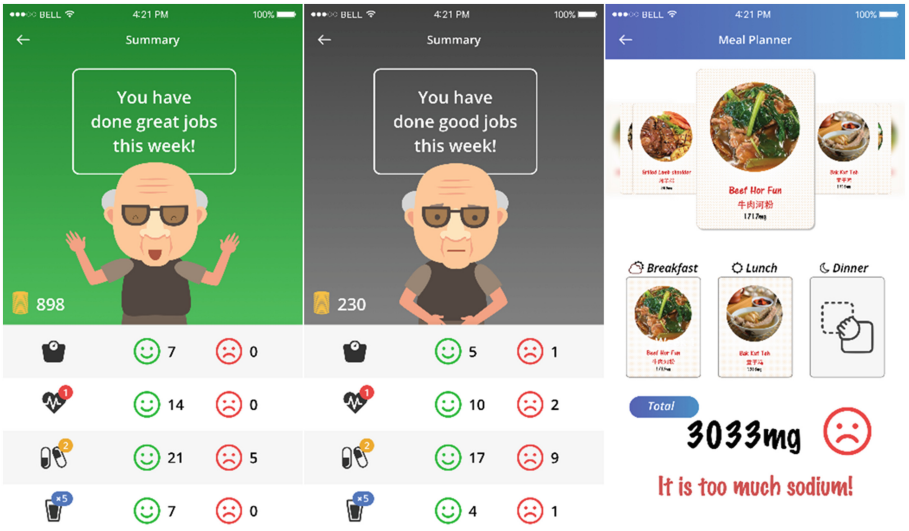

Fig. 5. Rewards and nutrition planning

Nutrition Planning. A mini-game is designed for patients to memorize healthy foods with sodium information as illustrated in Fig. 5. CHF patients are encouraged to play this game repeatedly to receive more reward points. It has over 40 common local foods, which potentially modify the dietary behaviors of the patients.

My Schedule. The mobile app offers clear goals and the day journey of self-care management to guide patients to perform activities as shown in Fig. 6. This feature is tightly integrated with push notification and reminder capabilities to constantly prompt for patients' actions. In additions, it also provides a one-stop screen for events related to patients' self-management activities such as play and learn, as well as, home visits by care givers.

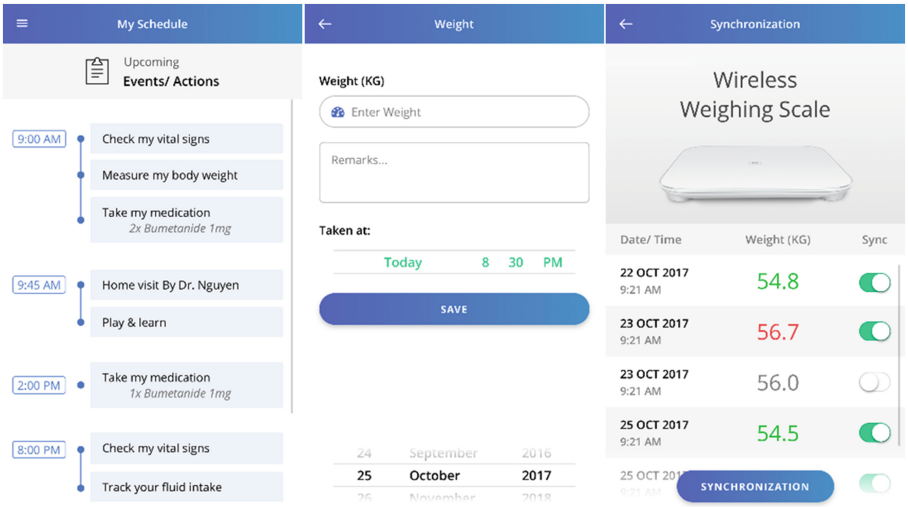

Fig. 6. My schedule and weight monitoring

Weight Monitoring. CHF patients are advised to monitor their weights in a regular basis. If there is a weight change of more than 2 kg in 3 days, an alert will be sent to care givers for timely interventions. Furthermore, Bluetooth-enabled weighting scales are supported by the mobile app to streamline to burden of manual inputs for patients.

Vital Sign Monitoring. The mobile app allows patients to monitor their blood pressures, and pulse rates several times per day as shown in Fig. 7. The design of this

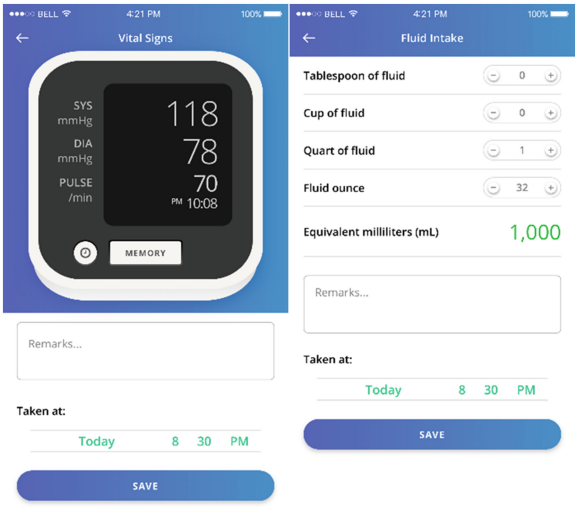

Fig. 7. Vital sign monitoring and fluid intake management

features follows conventional blood pressure monitoring devices; thus, it is friendly for older patients to avoid confusions for entering vital sign measurements.

Fluid Intake Management. The overloaded volume of fluid intake can worsen the symptoms of heart failure; and the patients are recommended to keep track of fluid intake daily as shown in Fig. 7. The optimal fluid management is 1500 mL over 24 h; the mobile app allows patients to enter estimated fluid intake with instant feedback for self-management.

Symptom Reporting. Symptoms have negative impacts on physical and psychological aspects of patients' daily life. The app allows patients to view the images of symptoms and to report warning symptoms quickly when they are worsening as shown Fig. 8. An alert will be sent to necessary psychological/social support actors to take appropriate action.

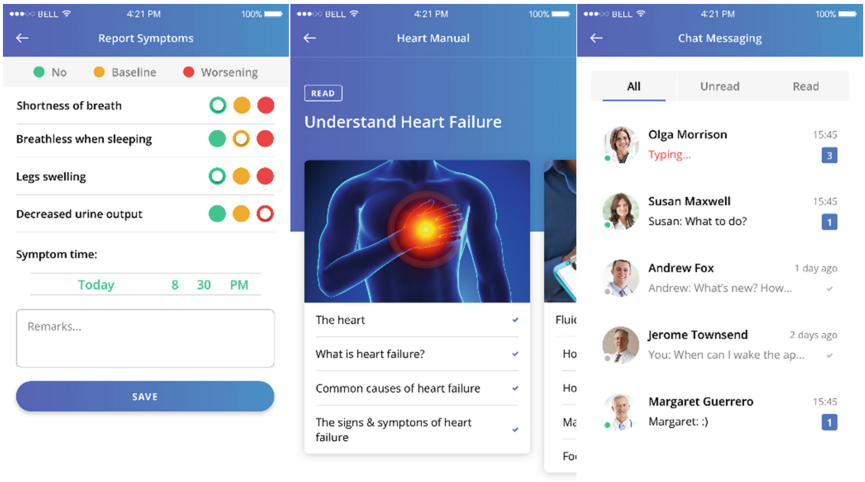

Fig. 8. Symptom reporting, education and social connectivity

Social Connectivity. The app allows the ability to connect with friends and family members as well as care givers via major social networking sites such as Facebook and Twitter. Once connected with appropriate permissions, the platform ensures the interactions and information exchange amongst the users in real-time. With the social support, the engagement between users and the mobile app would strengthen the frequent usage leading to a healthier lifestyle. In additions, in-app messaging between patients and psychological/social support actors is incorporated for timely recommendations and responses as illustrated in Fig. 8.

As illustrated in the methodological steps, the design process for gamification of mobile health entails the comprehensive understandings of activity systems towards achieving health-related outcomes. By exploring activities supported by technological

capabilities and game design elements, the design framework is capable of translating complex health interventions into practical design artefacts.

5 Conclusion

This paper redefines gamification beyond the use of game design elements and techniques in non-gaming contexts. It is the nexus between psychology and technology; where activities can be transformed by motivational affordances, as well as, technological capabilities. We propose a gamification design framework for mobile health for translating activity systems into practical design. The framework provides a structured procedure of steps: (i) identifying activity systems, (ii) modelling, (iii) transforming, and (iv) designing; which are clearly demonstrated through a mobile health self-management programme for patients with chronic heart failure.

This study contributes to the cumulative theoretical development of gamification and mobile health in three folds. First, the dialectal engagement between people and technology is highlighted in gamification to make clear the requirements for a theoretical discourse. Second, the proposed design framework is capable of transforming health interventions supported by mobile technologies towards better outcomes. Last but not least, the study provides a holistic guideline how to incorporate psychological and technological elements in domain-specific gamification.

There are multiple implications for designers and developers of mobile health. The paper introduces a unified representation of gamification design for developing gameful mobile health applications. Furthermore, its findings on design concepts of mobile-based self-management interventions are well-informed and practical for creating new programmes for other chronic diseases.

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