Nursing Informatics 2016
W. Sermeus et al. (Eds.)

doi:10.3233/978-1-61499-658-3-262

Gamification of Clinical Routine: The Dr. Fill Approach

Mark BUKOWSKI[a], Martin KÜHN[a], Xiaoqing ZHAO[a], Ralf BETTERMANN[a] and Stephan JONAS[a1]

[a] *Department of Medical Informatics, RWTH Aachen University, Aachen, Germany*

Abstract. Gamification is used in clinical context in the health care education. Furthermore, it has shown great promises to improve the performance of the health care staff in their daily routine. In this work we focus on the medication sorting task, which is performed manually in hospitals. This task is very error prone and needs to be performed daily. Nevertheless, errors in the medication are crucial and lead to serious complications. In this work we present a real world gamification approach of the medication sorting task in a patient's daily pill organizer. The player of the game needs to sort the correct medication into the correct dispenser slots and is rewarded or punished in real time. At the end of the game, a score is given and the user can register in a leaderboard.

Keywords. Gamification, health care, patient safety, medication plan, pill sorting

1. Introduction

Nowadays, patient safety is the worldwide priority for health systems. A main objective is the elimination of risks and threats to patient health [1]. One of the most common health risks directly affecting patient health are medication errors [2], which are defined as "any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the health care professional, patient, or consumer" [3]. Medication errors can occur within the entire medication delivery process [4]. They are to blame for 10-18% of all reported hospital injuries [5], and lead to increasing mortality rates as well as duration of hospital stays. Thereby, they are a major economical factor [6].

One reasonable approach is it to focus on human factors, particularly the nursing staff, which is highly involved in the entire medication process [7]. Continuing education and training of the nursing staff can reduce medication errors [2] and improve patient safety in general [8]. Additionally, many advances in healthcare education have already been made through serious games [9], which along with gamification use game design elements and mechanisms (e.g., points and leaderboards) to create motivation for non-game situations [10]. This leads to a significantly increased performance in general and specifically in an educational context [11]. For example, A. Higgins and M.M. Hannan show that by using gaming technology in a hand hygiene program, an enhancement takes place in hand hygiene compliance and

[1] To whom correspondence should be addressed: Stephan M Jonas, Pauwelsstr. 30, 52074 Aachen, sjonas@mi.rwth-aachen.de, Phone: +49 (0) 241 80 88 795, Fax: +49 (0) 241 80 33 88 795

technique as well as motivation of staff participation in learning [12]. Another example for positive learning effects is the web-based collaborative serious game eMedOffice used in the medical education to teach organizational aspects in medical practice [13]. Based on the already successfully applied serious games in health [8], it is reasonable to use serious games with gamification elements to deal with medication errors and especially to provide the possibility of training nursing staff in a motivational, risk-free, and cost-effective environment [8, 9].

Here, we present an interactive serious game called Dr. Fill, which provides a real world gaming environment. The player acts as a nurse, filling a patient's daily pill organizer according to its requirements. During the game, the placed pills are recognized and immediate feedback on success and errors is provided. In the end, the results of the entire dispensing procedure are presented on a final game report as well as on a leaderboard. In this work the structure, the current results, and future work of Dr. Fill are discussed.

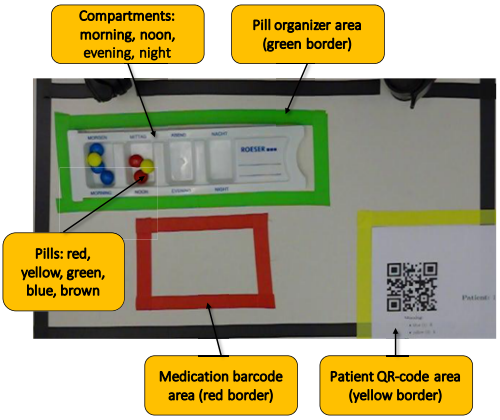

Figure 1. Game board with color-coded areas.

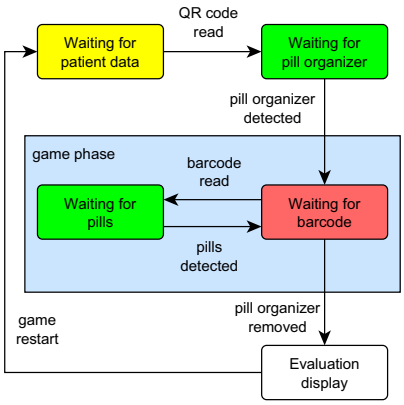

Figure 2. Gameflow with game phase, colors indicate board areas.

2. Methods

2.1. General Game Principle

The game Dr. Fill observes and scores a person who is filling a pill organizer. The game is played on a game board with different color-coded areas (Fig. 1) and structured as follows (Fig. 2):

1. Game start: The player places the patient information and an empty pill organizer on the game board. The game phase starts and the time is recorded.
2. Game phase: The player fills the container with pills according to the medication plan into compartments. First, the medication is indicated by placing the barcode of the medication box on the game board and then putting the pills into the organizer. This step is repeated until the user ends the game.

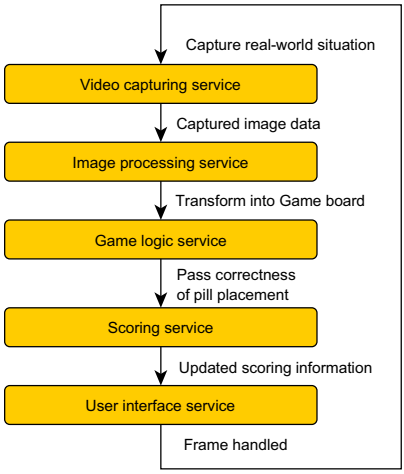

Figure 3. Services and interactions.

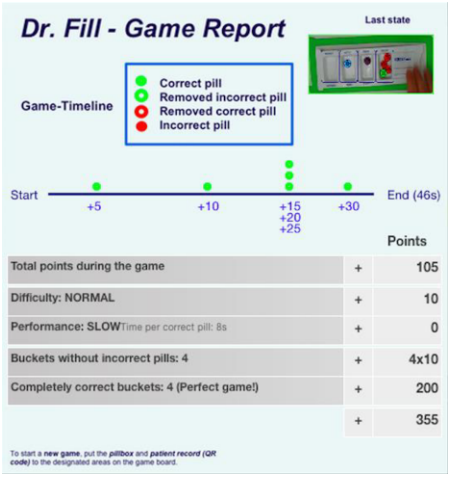

Figure 4. Game report.

3. Evaluation phase: The player ends the game by removing the pill organizer. The time counter then stops and the evaluation of the player's performance in terms of correct/wrong pills and time are displayed.

2.2. Implementation

The serious game Dr. Fill is a Java application. The software architecture is composed of two parts: Part one consists of several interconnected services that provide inputs and outputs and communicate with each other using a common data structure - the *Game board* (Fig. 3). The services represent different tasks that have to be performed in the game: (i) image acquisition, (ii) image recognition and processing, (iii) game logic, (iv) scoring, and (v) the rendering of the UI. Part two is a classical game loop, in which each service is called subsequently to perform its task in each frame, providing its output to the following services. In every frame, the current game situation of the real world is mapped into a corresponding *Game board* data structure, which the services access to perform their tasks and share messages/data. For the image recognition, the external computer vision library *OpenCV* (OpenCV.org) is used. The GUI is realized using the UI library *SWT* (eclipse.org/swt).

2.3. Services

The services orient themselves along the different tasks in the game and are called for each frame.

- *Video capturing*: retrieves and preprocesses images from the camera.
- *Image processing*: converts each image into a *Game board* structure. The Quick-Response (QR) code is scanned and the expected patient's medication determined. The placed pills are recognized in number, color, and the locations of the pills.

- *Game logic:* determines differences between the current and last *Game board* structures and checks for inserted or removed pills. Each changed pill can be either a wrong or a correct pill that has been placed or removed.
- *Scoring*: calculates the point change depending on the reported change, i.e., by rewarding correctly placed pills or penalizing wrongly placed pills.
- *User interface*: updates the recognized game situation and point score.

2.4. Evaluation of Player's Performance

After a game is finished the player is shown the performance in the form of a timeline (Fig. 4). Placement and removal of all pills, the breakdown of the attributed points, and a table explaining the calculation of bonuses are shown. Bonus points can be gained by minimizing the time needed to complete the task and by placing only correct pills or placing a number of correct pills in a row. The difficulty of the medication plan based on pill arrangement and number of pills is also taken into account.

After that, the user is also displayed a high score board to illustrate how he or she performed in comparison to other players.

3. Results

The latest version of the interactive serious game Dr. Fill is fully applicable. It supports live and recorded video-stream data and detects a pill organizer with four compartments, a 2D barcode for the medication container, a QR barcode for the patient assignment and the related medication requirements, the placed and removed pills, and occurring obstructions.

As a first evaluation, 25 games were performed and recorded in order to calculate the pill recognition rate of the final game state of the placed pills: each of the five test subjects played five gaming rounds. Three gaming rounds were aborted because the game board and the QR code were not recognized. The recognized pills of the final game state were compared to the actually placed pills. Out of 314 placed pills in total, 307 were recognized correctly for a recognition rate of 97.77%.

4. Discussion

The game Dr. Fill provides a training game for healthcare professionals to evaluate their own performance on the common task of pill sorting. The initial quantitative evaluation of the game shows a good pill recognition result but it can be further improved. So far, the pill detection is limited to colored chocolate lentils (M&Ms). While using chocolate is valid for a training exercise, and might even increase compliance, more realistic versions of the training tool might be needed. This could be achieved by either marking pills with fluorescent dye or computer-readable codes, or using real medication and advanced image processing, for example, spectrographic imaging and shape detection.

The current game aims at motivating the user by showing shortcomings and error-proneness of the given task. However, a more thorough evaluation of the designed system needs be performed through future studies:

- Short-/mid-term effect study: participants use the game as training device once per week for a short period of time. The study will measure the short-term benefit of the game regarding improvement of speed and/or accuracy. Alongside, usability of the system and improvements in motivation will be measured.
- Long-term effect study: the study will evaluate the long-term effects of a permanent serious game by measuring the impact of gamification on motivation, alert fatigue [14], and technology dependency.
- Scoring system study: the study will determine how points should be awarded or penalized to increase motivation in a real-world scenario.

A user acceptance testing is planned for July 2016. Further developments of the game will focus on the integration of badges and levels to foster long-term motivation.

5. Acknowledgments

Finally, we want to thank Mirko Kugelmeier and Christian Plewnia for their effort spent in this project. Without their input in our group meetings and the actual implementation, this project would not be on the stage it is now.

References

[1] H Hamishehkar, S Valizadeh, M Rasekhi, H Hamishehkar, M Asadollahi, Medication errors in oral dosage form preparation for neonates: the importance of preparation technique, J Res Pharm Pract 4 (2015), 147-152.
[2] C Hayes, D Jackson, PM Davidson, T Power, Medication errors in hospitals: a literature review of disruptions to nursing practice during medication administration, J Clin Nurs (2015), 1-14.
[3] National Coordinating Council for Medication Error Reporting and Prevention, About medication errors (2015), http://www.nccmerp.org/aboutMedErrors.html.
[4] B Durham, The nurse's role in medication safety, Nursing 45 (2015), 1-4.
[5] F Cebeci, E Karazeybek, G Sucu, R Kahveci, Nursing students' medication errors and their opinions on the reasons of errors: a cross-sectional survey, J Pak Med Assoc 65 (2015), 457-462.
[6] MA Cheragi, H Manoocheri, E Mohammadnejad, SR Ehsani, Types and causes of medication errors from nurse's viewpoint, Iran J Nurs Midwifery Res 18 (2013), 228–231.
[7] I Choi, SM Lee, L Flynn, C Kim, S Lee, NK Kim, DC Suh, Incidence and treatment costs attributable to medication errors in hospitalized patients, Res Soc Adm Pharm (2015), online first.
[8] F Ricciardi, LT De Paolis, A comprehensive review of serious games in health professions, Int J Comp Game Tech 2014 (2014), 1-11.
[9] S de Ribaupierre, B Kapralos, F Haji, E Stroulia, A Dubrowski and R Eagleson, Healthcare training enhancement through virtual reality and serious games, In MA Minhua, LC Jain, P Anderson (Eds.), Virtual, augmented reality and serious games for healthcare 1 (9-27), Springer Berlin Heidelberg, 2014.
[10] A Domínguez, J Saenz-de-Navarrete, L de-Marcos, L Fernández-Sanz, C Pagés, JJ Martínez-Herráiz, Gamifying learning experiences: practical implications and outcomes, Comp Edu 63 (2013), 380-392.
[11] ED Mekler, F Brühlmann, K Opwis, AN Tuch, Do points, levels and leaderboards harm intrinsic motivation: an empirical analysis of common gamification elements, Proceedings ICGDRA - Gamification '13, ACM (2013), 66-73.
[12] A Higgins, MM Hannan, Improved hand hygiene technique and compliance in healthcare workers using gaming technology, J Hosp Infect 84 (2013), 32-37.
[13] A Hannig, N Kuth, M Özman; S Jonas; C Spreckelsen, eMedOffice: a web-based collaborative serious game for teaching optimal design of a medical practice, BMC Med Edu 12 (2012), 104-118.
[14] AS Kesselheim, K Cresswell, S Phansalkar, DW Bates, A Sheikh, Clinical decision support systems could be modified to reduce "alert fatigue" while still minimizing the risk of litigation, Health Affairs 30 (2011), 2310–2317.