Using Gamification for Reducing Infections in Hospitals

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Abstract. Hospital acquired infections are one of the biggest problems healthcare field is facing, which can end up in an increasing quantity of deaths, extra-days of hospital stay and costs for both hospital and patient. Performing hand hygiene is a simple and inexpensive prevention measure, but healthcare workers compliance with it is still far from desired. Direct observation is an effective but costly and time-consuming approach to assess healthcare workers' performance. This paper proposes a gamification solution for providing healthcare workers with feedback regarding their hand hygiene habits, aiming at change their behavior and optimize their performance. We went through two iterations of a Design Science Research Methodology, whose activities were performed on an intensive care unit of a Portuguese hospital. Nurses working on this unit were our focus group throughout the whole research. The proposal was evaluated using a process designed according to a DSRM evaluation framework. Despite the identified indoor location technologies' limitations, which made it impossible to fully test the solution, we were able to conceptually validate the proposal, which appears to be promising in improving nurses' awareness.

Keywords: hospital-acquired infections, hand-hygiene compliance, healthcare workers, automated monitoring systems, gamification, behavior-changing

1 Introduction

Hospital-acquired infections (HAIs) are infections acquired by patients in a hospital or other healthcare facility while receiving treatment for medical or surgical conditions, in whom the infection was not present at the time of admission [1][2]. Although preventable, these infections cause more deaths than AIDS, breast cancer and auto accidents together [2]. It is one of the biggest problems healthcare field is facing, leading directly to around 37 000 deaths, 16 million extra-days of hospital stay and €7 billion financial losses of direct costs, only in the Europe [1]. It can be promoted by several factors, including healthcare workers (HCWs) poor hand hygiene (HH) compliance, which is the main source of HAI [3].

Performing HH at the right times is a simple and inexpensive prevention measure that can save lives, but this adherence is still suboptimal among HCWs [4], whom link this to factors like forgetfulness, lack of time, lack of guidelines' knowledge, etc.

Direct observation is the standard approach to monitor HCW's performance and provide feedback, but it is costly and time-consuming. Hospitals need to come up with innovative ways for monitoring HCWs performance and give them feedback.

Automated monitoring systems (AMSs), which can electronically determine when a HCW uses an alcohol-based hand-rub (ABHR) dispenser or a sink, have emerged during the last few years and they are promising in improving HH compliance.

Gamification is a recent but popular approach for bringing fun to processes related to non-gaming contexts, aiming at engage and motivate people to achieve their goals.

To address the problem of the poor adherence of HCWs to HH compliance, which in turn leads to an increasing number of HAIs, we developed a gamification solution that, using data collected regarding HCWs' HH compliance, can provide them with feedback in a funny and engaging way. Our goal is to create awareness regarding HCWs' actual HH compliance, trying to change their behaviors and optimize their performance.

We adopted Design Science Research as the methodology to conduct this research because it is based on an iterative process, which allowed us to incrementally design, develop, test and evaluate a solution that is align with the organization and our end users' needs [3]. Demonstration and evaluation activities were performed in an Intensive Care Unit (ICU) of a Portuguese hospital, whose nurses constituted our focus group throughout the entire research.

2 Related Work

In this section, which corresponds to the "Identify problem and motivate" step of DSRM, we present the results of our analysis of the literature related to our study.

2.1 Monitoring Hand Hygiene Performance

Monitoring HCW's HH performance is an important element of multimodal HH promotion programs [4]. To assist this, WHO proposed a framework for understanding, training, observing and communicating HH performance [5]. "My five moments for hand hygiene" links specific moments to HH opportunities. Visual representation of the 5 moments is presented in Figure 1.

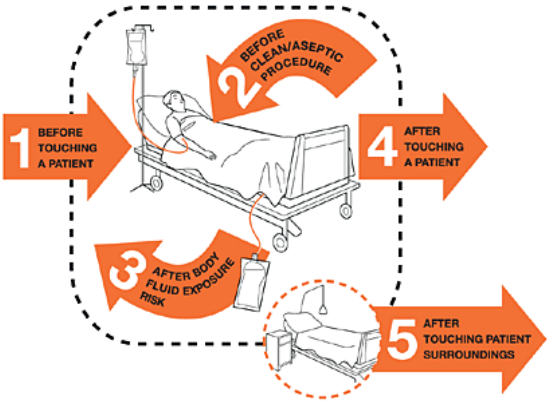

Figure 1 – "My five moments for hand hygiene" (taken from [5]**)**

HH must be performed **before touching a patient**; **before a clean/aseptic procedure**; **after body fluid exposure risk**; **after touching a patient** and **after touching patient surroundings**. By being an easy-to-remember model, HCWs efficacy and observations' accuracy can be increased when it is used.

Direct observation, observation of HCWs' HH practice by professional observers, is the standard for monitoring HH compliance. Despite being the method that provides the most accurate data and the only one that allows technique evaluation, it is costly, time-consuming and susceptible to several biases.

AMSs can electronically identify when an HCW uses a sink or an ABHR dispenser. Exact quantitative results are generated from automatically collected data and used to examine trends regarding HH compliance value over time. However, there are some remaining questions to concern about: accuracy, costs (which can be high, depending on the chosen technology), ethical questions (HCWs can be sceptical about accepting being monitored this way), etc. Some studies, like those performed by Levchenko et al [6] and Swoboda et al [7], are attempting to prove that these solutions can effectively lead to a better HH compliance, and so far they appear to be promising in improving monitoring performance and HH compliance among HCW.

One important component of an AMS is the indoor positioning system (IPS), which determines the current location of a target in an indoor space. There is no standard technology for indoor location (like we have GPS for outdoor location) because the indoor environment poses much more challenges, like its size limitation (thus, accuracy requirements are different) and the signal attenuation due to buildings' construction materials. A wide range of technologies, methods and techniques is available, and they must be chosen depending on the system's requirements.

2.2 Gamification

Gamification is a recent but popular approach which can be defined as "the use of game elements and game-design in non-game contexts" [8] to "engage and motivate people to achieve their goals" [9]. It aims at stimulating people's intrinsic motivation in doing an activity by trying to make it rewarding for itself. This way, we are able to create incentives without incurring into high costs.

Non-game contexts involve real-world problems and goals. In particular, gamification is used in behaviour change contexts to promote new and better habits in a population, for them to produce desirable outcomes. The process of designing a gamified experience should be iterative, meaning we need to build a solution (after defining our objectives, desired target behaviours and players), let our players try it and change it based on their feedback, in order to align it with their needs.

It is important to distinguish gamification from serious games, two different concepts often confused. Although both are related to gaming, serious games are full-fledge systems used, in the majority of time, for educational purposes, while gamification is about using parts of games in an already existing process.

These "parts" are called game elements, and we can consider it as a toolkit for building a game [8]. Not all of these elements are tangible, but they're all of huge

importance to understand the game (for example, the implicit rules). Werbach and Hunter propose a list of game elements divided into three categories [8]:

- **Dynamics:** elements at a higher level of abstraction; they correspond to the overall view of the gamified system that have to be carefully considered and managed, but are not directly entered in the game.
- **Mechanics:** processes that drive the action forward and create engagement. Each mechanic can be used to achieve one or more dynamics.
- **Components:** concrete forms that dynamics and mechanics can take (one component might be connected to one or more dynamics and/or mechanics).

In Table 1 we present some examples of game elements, following this classification. Note that the goal is not to incorporate all these elements in a gamification solution; instead one shall pick the ones that better serve our purpose.

Table 1 – Some game elements, classified according to the framework proposed by [8]

Classification	Concept	Description
Dynamics	Emotions	Curiosity, competitiveness, frustration, happiness
	Relationships	Social interactions
Mechanics	Competition	One player or group winds, and the other loses
	Cooperation	Players must work together towards a shared goal
	Feedback	Information about how the player is doing
	Win States	Objectives that makes one player or group the winner – draw and loss states are relative concepts
Components	Avatars	Visual representations of a player's character
	Badges	Visual representations of achievements
	Levels	Defined steps in player progression
	Points	Numerical representations of game progression

In the last few years, gamification has started to emerge in health related contexts, mostly in personal wellness improvement and medical education and practice solutions. Pereira et al [10] presented some state-of-art regarding the usage of gamification in healthcare contexts. Analyzed examples lead them to conclude that gamification can be successfully used in promoting healthcare and healthy habits.

However, this process is not simple and can be subject to some major concerns and bad practices that we must be aware of, especially in the healthcare field. For example, if HCWs are to experience a gamification solution, this must be designed such that the additional workload is as negligible as possible, because this can represent a very impeditive barrier to the effectiveness of the project [11]. Also, when collecting data, we must be sure to meet all the consents from the players, by means of terms of service agreement and/or a privacy policy, stating what data and why we're collecting it, what we are going to use it for and other related practices [8].

4 Research Proposal

The main objective of our work was to explore the potential of gamification to improve HCWs' HH compliance. More specifically, we tried to create awareness regarding their current HH compliance rate and promote an individual behaviour change and performance optimization. In order to fulfil this objective, reduce the number of HAIs and improve HCWs and patients safety, we developed three artifacts.

The first artefact, the IS model, is represented in Figure 2.

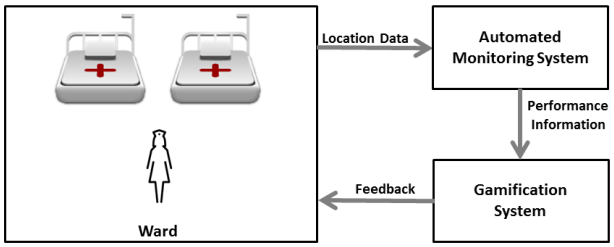

Figure 2 – IS abstract model

Without interfering with HCWs' regular practices, real-time data regarding HH opportunities and actions is automatically and continuously recorded using an AMS. HCWs' proximity to strategic locations (beds, ABHR dispensers, sinks, etc.) is first collected using an IPS and this data is then analysed with an algorithm, which implements the business rules that state when HH compliance occurs (for example: "If the HCW gets close to the patient's bed, he/she shall perform HH"). We structured these rules in another model (our second artefact) that represents the different HH opportunities that may arise and how they are complied or not, following WHO's "My five moments for hand hygiene" framework. As an example of the modelled rules, consider the situation when a HCW enters a room more than 30 seconds after leaving another room. If he/she goes to an ABHR dispenser or a sink, the system registers a complied HH opportunity; otherwise the system registers a non-complied opportunity.

Finally, this information is presented to the HCWs using a gamification solution that, making use of some game elements, provides feedback information in real time.

The third artefact is the instantiation of the IS model. Because it has changed through the iterations, its design and development will be presented and detailed throughout the following two sections, each corresponding to one of the iterations.

5 First Iteration

In our first prototype, we decided to use Estimote beacons technology [12] to build an IPS from scratch, since it was one of our least expensive options and it promised accurate values using a proximity-based technique. These beacons send BLE signals, which are detected by an Android application installed on a smartphone the nurse has to carry on his/her pocket. These signals allows the application to detect

if it is near the beacon or not (if it detects strong signals from a beacon placed in a sink, it means the nurse is near that sink). Every time we detect and validate (or not) an HH moment, the application will update the database.

A dashboard screen was developed, where nurses' compliance information is displayed during the shift, providing them with real-time feedback (Figure 3). It presents a bar chart composed by four bars (the number of nurses working per shift) indicating HH compliance performance value (we can consider this as the "shift **punctuation**"). Each bar is illustrated with similar avatars, just to provide an element of fun. We decided not to present nurses' real name in the screen in order to protect their privacy (this way, he/she will only be able to know which sensor it is using, but will not know which sensors its colleagues are using). By using these elements, we are exploring the mechanics of **feedback**, **competition** (providing the player with the currently highest punctuation with a bar of different color) and **win state** (the player with the highest punctuation at the end of the shift is the winner).

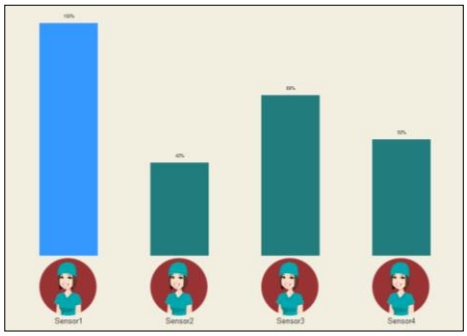

Figure 3 – Dashboard component of the gamification solution

5.1 Demonstration

The set of demonstration activities are described in the following sections.

5.1.1 Initial feedback from nurses

An initial meeting with the nurses was performed to gather feedback from them regarding the IS concept and some ideas we already had. Nurses enjoy the concept and think it is a unique and good opportunity to receive feedback regarding their performance (although they are sometime subject to audits, they said that this would give them a totally different experience). They showed little interest in components like badges because it would require them to use the system outside their labor hours. However, they found the avatars experience funny. None of them expressed concerns regarding being monitored and having their identity exposed in the screen. They believe that the language style used in the application should be colloquial, since some people would not find adequate to use a familiar language style in such system.

5.1.2 Preliminary experiments and simulation

Before starting the development of the first instantiation, we conducted some preliminary tests on a pack of Estimote beacons to check whether or not the

technology fitted our needs. First, we measured some distances between beacons and a tablet running Android (by means of a function from Estimote SDK). In all cases, either beacons were not detected inside the promised range or were detected with a low accuracy (the most accurate result presented an error of 1,9m). Afterwards, we developed a tool to collect, store and present information regarding beacons' RSSI values in the form of graphic, in order to test beacons' proximity detection feature. Beacons were placed a few meters apart and, carrying the tablet, we started approaching them one at a time to check if we could match our path in the graphic.

Following the instantiation development, a simulation was conducted to test the whole solution. Three beacons were placed on a lab, the Android application installed on a tablet and a laptop placed where we could see the gamification screen. We noticed that collected data was well processed and presented in the screen, although there were some problems in detecting the beacons. Sometimes we were placed right near a beacon and it was not detected by the application, while other times (in the exactly same situation) its presence was detected.

5.2 Evaluation

In this section we will describe how we are going to evaluate the outcomes of our proposal and confirm that it can be used to solve the problem stated.

5.2.1 Initial feedback from nurses

We believe that the gamification solution of this iteration is aligned with nurses' needs, and that it will have a positive impact on their daily routine. Despite expressing some resistance to future work ideas that would make them use the application outside their labor hours, we believe that after using it they can change their minds. However, this was one of top considerations to the next iteration.

5.2.2 Preliminary experiments and simulation

Tests performed on Estimote beacons showed us that estimating distances to them is unfeasible for our work, since results are not accurate at all, but a proximity-based technique can, at least, describe one's movements. The simulation allowed us to conceptually validate the IS, since it was possible to detect movements using proximity and to quantify compliance with some precision. However, it is evident that range and accuracy values promised by Estimote are far away from reality.

6 Second Iteration

For the second iteration, we used an IPS from Sensefinity [13]. It is composed by beacons, which use both Bluetooth and a proprietary protocol to communicate with tags using a proximity based technique. It works similarly to previous' iteration IPS, but instead of smartphones it uses tags that send messages to a server via a gateway.

Regarding the gamification component, we changed the avatars to differ between each other in the cap color, which corresponds to the name of the tag they are using

(as the typical board game pieces). We also introduced two new parts: e-mail functionality and an application to be explored outside nurses' labor hours. After the end of their shifts, nurses receive an e-mail, which provides feedback regarding their HH compliance rate and has a link to the application, for further information. The application (Figure 4) makes use of several game components to explore different mechanics and activate some dynamics. For example, we use points and levels to provide feedback and badges that promote cooperation between nurses working on a shift. Dynamics we want to activate include emotions, since we want HCWs to become aware and reflect about their performance, and relationships, because cooperation and competition (two mechanics we want to explore) are based on this.

Figure 4 – Homepage of the gamification application to explore outside labour hours

Having this, all nurses are able to receive the feedback they are interested in with little additional – which was one of our main concerns through all design and development phases.

6.1 Demonstration

The second iteration was composed by two field studies, where beacons were deployed in the three rooms of the ICU. One screen was placed in the nurses' room, connected to one of ICU computers, presenting the dashboard component of the gamification solution to provide real-time feedback regarding their HH compliance.

During the 4-day first field study we only got to test the IPS, which had several hardware problems that were spotted and solved. Together with hospital's GSM coverage limitations (which interfere with IPS correct functioning), this led to a situation where the system was not functioning properly: it was sending way more messages than expected. Although nurses did not have a chance to experience the solution during this period, we were able to meet and collect more feedback from them. They aware us that beacons placed in beds often fall from their places, especially when beds are being cleaned. They also reported one case when a beacon fallen during a surgery. At the end of the study, all the equipment was removed from the ICU for further refinements.

At the beginning of the second field study, the chief nurse changed the position of some ABHR dispensers that are usually they are fixed in a table (which is positioned near the bottom of beds), instead of being fixed at the bottom of beds. Nurses were aware not to change it back. To check whether or not the IPS worked correctly, a nurse was handed a tag for her to carry for two hours. She was most of the time in one room (approximately 1h45min), and after that went to the nurses' room (where the IPS was not installed). Only three location messages were received, being one of them from a beacon placed in a room the nurse never entered. Nurse feedback was that she barely noticed the tag on the pocket. Another important thing to highlight is that, few days after deploying the system, ABHR dispensers placed in the beds of the four-bed room were placed back on the tables, despite the chief nurse aware for the nurses not to change them back.

6.2 Evaluation

Due to the problems that have arisen during the field study, we were not able to test the accuracy of the whole system. But it was evident that Sensefinity's technologies needed refinements, both in hardware and software terms.

Because the IPS came back to the second field study with the exact same problems it had during the first one, it was not possible to test it with the gamification application because the IPS either did not work at all (which we believe could be due to problems in the hardware and/or the weak GSM coverage at the hospital) or did not work well. It is evident that Sensefinity's solution still needs considerable and deep refinements before it can work properly and be applied in a healthcare context.

However, from the participant nurse's feedback, we believe we have validated the choice of asking nurses to carry the tag on the pocket, since it was transparent for the nurse and did not affect her practices.

Other major consideration is the fact that beacons are often falling from their places, since it does interfere not only with the system correct functioning, but also with HCWs' regular practices. Also, following the results from the first field study, we believe that a less invasive IPS should be used, since beacons placed in the nurses' field of action can interfere with their regular practices (by falling off frequently or by implying a change of configuration in the ward).

7 Conclusion

Since first iteration, results showed that the IS was promising in improving nurses' awareness regarding HH compliance. Although we were not able to fully deploy the solution in the unit, feedback gathered from evaluation activities and conferences attended suggests that it would have a positive impact on their daily routine.

By involving nurses in the project since the beginning, it was possible to align the IS with their needs, which was confirmed by the results and their feedback. In projects like these, where a solution is being designed for the benefit of someone, is important to involve them since the very beginning in order to enable a higher sense of ownership in the process and better understand our end users' requirements.

It is also important to mention that, although indoor location technologies strongly evolved during the last few years and have been successfully applied in areas like retail, their precision is still not enough to be applied in the healthcare field, where the areas of interest are much smaller (down to centimeters).

We believe this study was a first step towards the implementation of an innovative approach. Finding an accurate IPS to track HCWs inside the hospital is a mandatory task regarding future work. After that, further tests might include involving other HCWs (such as doctors) and deploy the IS in units with care models different from the ICU. To finish, a key concern is how to keep HCWs engaged when the novelty feeling disappear. This could be done, for example, by planning new feature releases.

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