

# Improving Nurses' Hand Hygiene Compliance using Gamification

Rita Marques<sup>1,2</sup>, João Gregório<sup>1</sup>, Fernando Pinheiro<sup>3</sup>, Pedro Póvoa<sup>3</sup>, Miguel Mira da Silva<sup>2</sup>, and Luís Velez Lapão<sup>1</sup>

<sup>1</sup>Instituto de Higiene e Medicina Tropical – Universidade Nova de Lisboa, Lisboa, Portugal

<sup>2</sup>Instituto Superior Técnico – Universidade de Lisboa, Lisboa, Portugal

<sup>3</sup>Centro Hospitalar de Lisboa Ocidental – Hospital S. Francisco Xavier, Lisboa, Portugal

**Abstract.** Healthcare 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 the hospital and the patient. Performing hand hygiene is a simple and inexpensive prevention measure, but healthcare workers compliance with it is still far from desired. Recognized hurdles are lack of time, forgetfulness, wrong technique and motivation. Besides, nurses' perception about their compliance is disturbed by a busy schedule. This study aims at exploring the use of gamification to promote nurses' HH compliance self-awareness and action. Real-time collected from an indoor location system will provide feedback information to a group of nurses working in an ICU ward. In this paper we present our research's motivation and methods, along with the collected results and its discussion.

## 1 Introduction

Healthcare acquired infections (HAI) are infections that are neither present nor incubating when a patient is admitted to hospital [1][2]. HAIs' increasing number 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 [3]. They are a risk that hospitals must control to manage healthcare economically and safely for patients, whom can become disable at long-term or even die. Although preventable, by means of hand hygiene (HH) compliance, these infections are the most adverse event a patient can experience during care delivery, and cause more deaths than AIDS, breast cancer and auto accidents together [4].

Nonetheless, leading busy healthcare workers (HCW) to comply with HH remains puzzling. Recognized hurdles are lack of time, forgetfulness, wrong technique and motivation. Besides, nurses' perception about their compliance is disturbed by a busy schedule.

As HCW's HH compliance rate decreases, the number of patients affected by HAI increases [5], so it becomes crucial to understand this problem's root and try to cope with it.

Having this, it becomes crucial to monitor nurses' compliance with existing guidelines and provide them with feedback regarding their performance. Direct observation, the observation of HCW's HH practice by professional observers, is the

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standard approach to fulfil this task, but it is costly and time-consuming. Hospitals need to come up with innovative ways of doing this.

Automated monitoring systems have emerged during the last few years, and can electronically identify when an HCW uses a sink or a handrub dispenser. It provides exact quantitative results, which can be used to examine trends regarding the value of HH compliance over time.

Some studies 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 improve HH compliance among HCW. Levchenko et al [10] provided eleven nurses working on a nursing unit with personal wearable electronic monitors which monitored, recorded and prompted reminding signals regarding their HH practices. Despite this study's short duration, they were able to demonstrate the feasibility of using such technology to improve HH performance, since the HH compliance rate during the trial was higher than the rate generated by the baseline observational study. Swoboda et al [11] conducted a three-phased study in an intermediate care unit. During phase I HH compliance was measured both by means of direct observation and electronic monitoring. Phase II included both electronic monitoring and computerized voice prompts for failure when HH was not performed on room exit. Finally, phase III was only electronically monitored. Considering electronic monitoring system's data, HH compliance improved 37% in phase II and 41% in phase III, comparing with results from phase I. They concluded that the electronic monitoring system provided effective feedback regarding HCWs HH compliance and improved HH performance.

Gamification is a recent but popular approach which can be defined as “the use of game elements and game-design in non-game contexts” [6] to “engage and motivate people to achieve their goals” [7], providing a whole different user experience. It aims at stimulating people's intrinsic motivation in doing an activity by trying to make it rewarding for itself.

Game elements are the “toolkit” for building a game [6] and they must be chosen in the end of the process of designing a game, after some variables are analyzed and defined (goals, behaviors we want to stimulate, our target players, etc.). Werbach and Hunter provide a list of game elements divided into three categories with different levels of abstraction: dynamics (at the top), mechanics and components (at the bottom) [6].

In the last few years, gamification has started to emerge in health related contexts. The majority and most well-known solutions relate to personal wellness improvement, helping people adopting healthier life habits (eating better, exercise more, etc.). Others are more directed towards medical education and practice, where gamification can have an important role in improving processes typically repetitive, tedious and boring by creating engagement among HCWs and improve their performance [16]. Nike+ [8] is an example of a successful gamification application, and it is perhaps the most mentioned one. It gamifies personal fitness by measuring the number of miles run and providing feedback using game elements like points, badges, progression bars, etc.

Pereira et al [16] presented some state-of-art regarding the usage of gamification in healthcare contexts. Presented and 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. Some people believe that gamification is just a “marketing hype” used to lead people to engage into tasks that do not fit their better interests [12] (this phenomenon is called “exploitationware” [12]). Others find it hard to believe that that this is nothing more than playing games and that will act as a distraction at work [16], very inappropriate to a serious context. Another huge barrier is applying and receiving ethical recognition to conduct trials that are typically designed for drugs and new equipment that have a long-term development [17], which contrasts with the iterative process for implementing gamification solutions. 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 [12]. 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 [17]. To finish, players might be tempted to play around the system’s rules and to create their own rules – what we call “gaming the game”. This represents a problem because players can lose sight of the solution’s main purpose(s) (for example, eating better) or can interfere with data collection for researching purposes (for example, when trying to educate HCWs).

There is one last concern, more directly connected to the design of a gamification solution, which is called “pointsification”, and corresponds to focus deeply on giving rewards and neglecting the players’ experience. As the name suggests, it happens when a designer creates what he believes is a gamification solution just by adding points to a process, and expecting that this can create engagement, which is much rarely true. People play to be better, to overcome obstacles and socialize with other players. This is one main reason why so many gamification solutions fail.

This study aims at exploring the use of gamification to promote self-awareness and action regarding nurses’ HH compliance. An automated monitoring system was used to collect data in real time, and a gamification application provided feedback information to a group of nurses working in an ICU ward, in a fun and engaging way. As we have already mentioned, there is evidence to support that automated monitoring systems can be successfully used to improve HH compliance. By applying a gamification layer, we aim at creating a fun environment in the ICU and to engage nurses even more in complying with HH moments.

We start this paper by defining the methods we used to conduct our research. The already collected results will be presented, followed by their discussion. We end with future work statements and a conclusion.

## **2 Methods**

In this section we present the methods used in our study. We chose to adopt a design science research methodology since 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 [9]. Our solution consists on an automated monitoring system combined with a gamification layer to promote nurses’

engagement. It was already presented to its target users (the nurses) and its usage was simulated in both non-real environment (by non-real users) and real environment (by a real user).

### 2.1 Design and implementation of the solution

The first component of our solution is an automated monitoring system built with innovative smart beacons and smart tags, which use both Bluetooth and a proprietary protocol (also operating on the 2.4GHz frequency band) to communicate, and a proximity based technique.

Smart beacons are the passive devices to be positioned at specific locations in the hospital (near beds, sinks, etc.). Smart tags, which are physically identical to smart beacons, are the active devices in this system, which was built using a proximity based technique. More specifically, the smart tags (which are carried by the nurses) receive information from smart beacons and they send a message to the server (communicating its position, the smart beacon detected and the current time) whenever they are approaching a smart beacon or walking away from it. Analyzing the messages stored in the server, we are able to detect nurses' position over time.

The next step is for the system to detect and validate HH moments. To achieve this, we built an algorithm based on the the World Health Organization (WHO)'s "My five moments for hand hygiene" framework [10], which links specific moments to HH opportunities (Table 1).

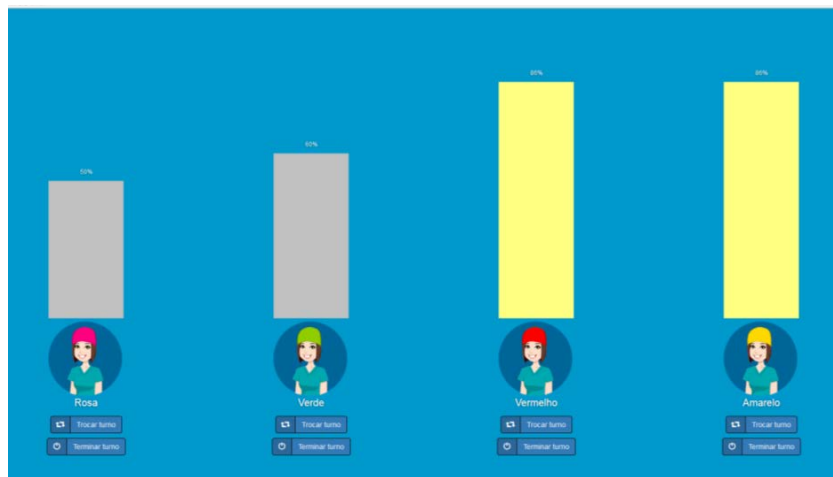
**Table 1: WHO's "My five moments for hand hygiene" framework (adapted from [10])**

Moment	Period where HH must take place	
	After...	Before...
1 – Before touching a patient	...the last contact with a surface in the health-care area	...the first contact with a surface in the patient zone
2 – Before clean/aseptic procedure	...the last exposure with a surface	...access to a critical site with infectious risk for the patient or critical site with combined infection for patient care.
3 – After body fluid exposure risk	...a care task associated with a critical site with body fluid exposure risk for the patient or critical site with combined infection	...the first contact with any other surface
4 – After touching a patient	... the last contact with a surface in the patient zone, <u>with</u> touching the patient	...the first contact to any surface in the health-care area
5 - After touching patient surroundings	...the last contact with a surface in the patient zone, <u>without</u> touching the patient	...the first contact to any surface in the health-care area

With this framework, we are able to create and implement business rules in our system (for example, if a nurse is approaching a bed, he/she must have approached an alcohol hand rub dispenser or a sink previously).

After data is collected from the ward and processed, we have information regarding each nurse's HH compliance.

Here is where our second component of the solution, the gamification application, comes into action. This application is partitioned in two parts. The first one is a one-page dashboard, which is presented in a screen located at the nurses' room. It displays nurses' HH compliance in real-time, in an anonymous way. A screenshot of this dashboard is presented in Fig. 1. A nurse can only be identified by its smart tag name, which corresponds to a color, represented in the avatar's cap.



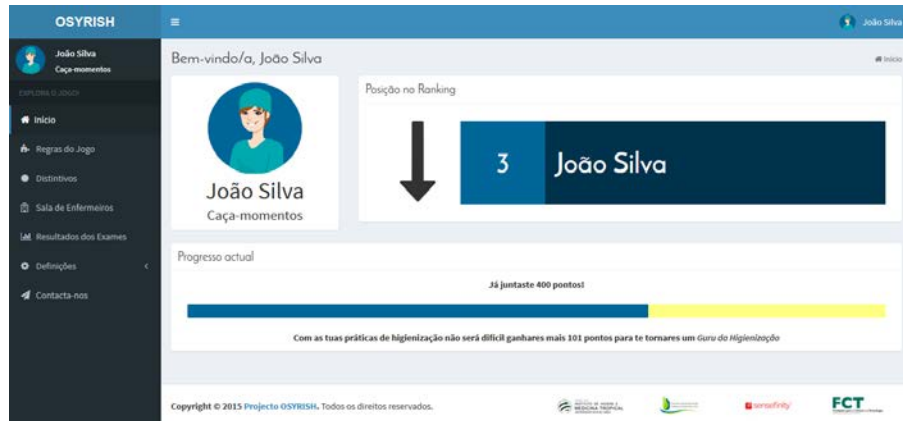
**Fig. 1: First part of the gamification solution: a dashboard screen that provides feedback in real-time to the nurses working on a shift. This is always presented in a screen in the nurses' room**

Nurses indicate when they start or end a shift using this application. After the end of their shift, they receive a simple e-mail, which provides feedback regarding their HH compliance rate and has a link to the second part of the gamification application, for further information. This part of the application is to be used outside their labor hours and provide a wider range of game elements for nurses to interact with.

In Fig. 2 the home page of the nurses' profile is presented. It shows the player's avatar, a partial leaderboard (to promote competition), points and levels (that means, their progression). There are other functionalities, like a platform for players to see each other's progression and communicate and a list of badges to achieve.

With the gamification application, we aim at solving the compliance problem by engaging and motivating people to achieve specific goals [11], using several and distinct game elements (feedback, competition, points, levels, badges, etc.).

The presented solution is the result of several iterations of the DSRM process. In each of them, we met the end users (the nurses), developed a prototype and tested it in a chosen environment (real or unreal). This method will be further explained in the following subsections.



**Fig. 2: Second part of the gamification solution: an application to be used outside nurses' labor hours, providing a wider range of game options**

Nurses' feedback was taken into consideration during the whole process, and several functionalities derived from their thoughts. For example, because they were a little skeptical in using some game elements that required them to access the system outside their work time, we decided to include the e-mail functionality in the system. This way, all of them are able to receive the feedback they are interested in with little additional workload (they only have to indicate they are starting and finishing a shift, and to consult their compliance rate during the shift) – which was one of our main concerns through the whole design and development phase. However, if they want to, they can follow the provided link and explore the application outside their labor hours. Our goal with this is to induce some curiosity and see whether or not they are moved into using the solution.

## 2.2 Meeting with the users

Nurses were involved in the project since the beginning, and we have met with them several times during the development of the solution, more specifically before system's development and each time we performed significant changes. Although we were not able to meet with all of them in the preliminary meetings, we got all the consents to participate in the study by means of a consent form, stating the data we were collecting, why we were collecting it and what we were going to use it for.

In these meeting sessions we presented the information system (IS) to the four nurses working on that shift, aiming at gathering feedback regarding their feelings about it. Their thoughts were not recorded, but the main conclusions were written down.

## 2.3 Simulation

In order to validate if the solution was technologically working correctly, it was tested in a simulation in a non-real environment by non-real users, more specifically the research members. A protocol was written and executed, and after that we looked at the HH compliance rate computed, which was compared with the expected rate.

After this, the IS was installed in the ward. We placed one screen in the nurses' room and 26 beacons in specific positions: in the rooms' doors, in each alcohol-based hand rub container, in each sink and in each bed. This way, the system would be able to trace a nurse's position along time based on the proximity to each beacon.

To analyze both the impact of the IS's usage by a real user and whether the solution worked correctly in the hospital environment or not, we asked one nurse from the ICU ward to carry a smart tag during a workday. During this period, her thoughts were written down, and in the end one small and informal interview was performed in order to understand how the gamification solution impacted her work. Data collected by the automated monitoring system was compared to a previously established baseline (built with respect to an observational study performed during a workday, where she was one of the professionals observed by two trained researchers, regarding whether or not the necessary HH took place) to measure the changes in behavior.

### **3 Results**

We collected results from the already completed work, which are presented in this section.

#### **3.2 Feedback from the nurses**

The group of nurses to whom the IS was presented to enjoy the concept and think it is a unique and good opportunity to receive feedback regarding their performance (although they are sometimes subject to audits, they said that this would give them a totally different experience). Although worried with the accuracy of the location system, they found the avatars experience funny. In the first meeting, when we presented the concept, they showed little interest in components like badges, virtual goods and content unlocking because it would require them to use the system outside their labor hours. They, however, liked the concept of leaderboards.

To finish, we asked them if they prefer to maintain their privacy (that is, information presented by sensor and not by HCW) or if they wanted their name (or a chosen nickname) to appear on the screen. They said that this was indifferent for them, since they had no problem in having their identity exposed in the screen.

#### **3.3 Simulation**

The simulation in a non-real environment by the authors of this paper presented good results. The system worked accordingly to our expectations, returning a HH compliance rate of 100% regarding the moments simulated. However, when testing it at the hospital, we noticed that these results were a false positive and that the system needed some refinements.

Regarding the simulation performed by the nurse from the ICU ward during one 12-hour shift, little data was collected for us to make assumptions regarding changes in behavior, in comparison to the baseline. Plus, as we already mentioned, the system still had some flaws in terms of accuracy. Nevertheless, the feedback received was that the nurse got happier as she progressed in the game, and whenever she noticed

that the rate had decreased (even if only a little), she felt the urge for being more aware of the HH moments. The participant nurse approved the measure as an opportunity to improve her performance. This nurse realized that she ended up consulting the webpage, even though she said she wouldn't in a first instance.

## 4 Discussion

Based on the results presented in the previous section, we can settle that the IS was conceptually validated, since we were able to detect the nurse's movements using proximity and to quantify the compliance with a good precision, which was only possible due to the indoor location system's capability of providing the nurses' position with great accuracy and in a real-time basis, despite using a radio-frequency based technology. After the refinements currently being performed, we believe that the system will be able to collect data with even better accuracy.

Nurses' feedback was taken into consideration during the whole process, and several functionalities derived from their thoughts. A good example is the e-mail functionality already presented and justified.

The results from the initial meeting with the focus group were confirmed, since the participant nurse approved the measure and believes, in long term, it can really improve her performance. Also, we verified the results we aimed at achieving with the e-mail functionality, since the nurse consulted the webpage. However, one huge limitation must be highlighted: our goal with this small simulation was to validate the concept and one nurse's opinion, and not to test the overall impact of the gamification solution in a ward. Thus, we were not able to analyze the impact of the interactions between colleagues and the nurse was not able to experience the cooperation and competition mechanics of it, which is of greatest importance in this study. This study's small duration (one work day) is also another relevant limitation.

Our gamification solution will be facing the barriers we previously mentioned, and it was built not only to fit HCWs needs but also to fight these barriers. Our main concern since the design phase was to keep the workload induced by the IS as low as possible, mainly during the shift. We believe that we achieved it, since nurses seem to accept the tasks of starting and finishing the shift in the applications as something that does not impose much effort. The nurse participating in the small simulation stated that her motivation in performing HH had augmented, thus we believe that the IS will increase motivation even more when nurses start to compete and interact with each other. Forgetfulness was fought since system's presence acts as a reminder for the nurses to perform HH.

Of course, players are different and will react differently to the system. In further tests we will try to understand the different type of players we have and refine the IS to please as many players as possible.

It is also important to highlight that the gamification application will not be used for monitoring purposes. Its goal is to create a fun environment and turn the process of cleaning hands not only as an obligation, but also as a thing that can make them progress in the game. Gamification tries to erase one of automated monitoring system's drawback of HCWs being afraid of being "watched" and "monitored".



Since, as we have seen, there is a direct relation between HH compliance rate value and the number of patients affected by HAIs, we believe that if we are able to improve HH performance we will also be decreasing the number of patients affected by HAI.

This system suffers from some of the typical limitations associated with automated monitoring systems. It is only able to detect compliance with moments 1, 4 and 5 of WHO's "My five moments for hand hygiene" framework. According to several studies, this means that we were able to detect 80% of the total HH opportunities [12]. There is some potential to observation bias: although there is no presence of a physical observer, nurses may have the sense of being observed, which can lead to higher (thus, unreal) HH compliance rates.

Results achieved were collected in an ICU, where the majority of the patients require full care for all daily activities like eating, bathing, dressing, etc. The same system deployed on units following different care models might present different results. Also, we only monitored nurses' HH performance, but it would be of importance to include physicians in further trials.

## 5 Conclusion

The impact of gamification on HH compliance is still under evaluation. Even though we only performed small validation tests to check whether or not the concept would work, so far the results show that the IS is promising in improving nurses' awareness.

A demonstration in the ICU ward is already planned. During a 5-day trial, 24 nurses will be using the gamification solution and will be provided with feedback regarding their HH compliance rate. Simultaneously, we will be observing their behaviors and reactions, trying to understand if they are comfortable with it and if they trust the presented results. We will also be focused on spotting technical issues that might be leading to undesired side effects of the system. In the end, we will analyze the gathered results and refine our tool, both in terms of improving our gamification solution and fixing problems that may emerge during the demonstration.

After this, our goal is to implement the solution in a unit of another hospital during a larger number of days. As we mentioned in section 4, the system might present different results depending on the care model the unit follows. This also applies to deploying it in different hospitals. It would be of interest to analyze the impact of these variables in our system's results.

To conclude, we believe that the IS is aligned with nurses' needs and that it will have a positive impact on their daily routine. Although we note some resistance to some ideas we discussed with the nurses regarding game elements, the nurse who participated in our initial test agreed that she ended up checking the system. We want to check if nurses' become curious about the IS and start exploring it (instead of just seeing and trying it on the meetings). From here, maybe they start using it on a daily basis.

It must be highlighted that by involving the nurses in the project since the beginning, a higher sense of ownership in the process was enabled and we were able to better understand their requirements.

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