CatCare: Designing a serious game to foster hand hygiene compliance in health care facilities

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Abstract. Lack of proper hand hygiene is often the source of hospital acquired infections. Despite many efforts, on average, health care workers still perform hand hygiene in less than 50% of the occasions in which they must. Serious games have been used successfully to achieve behavioral change in other health care domains. In order to tackle the complex problem of hand hygiene compliance we followed a design science research approach combining the build-phase with three evaluation cycles. In this paper, we present a preliminary design of a serious game to explore the possibilities of achieving better hand hygiene compliance of health care workers.

Keywords: hand hygiene, Serious Games, Augmented Reality, health care

1 Introduction

Healthcare associated infections (HAIs) are infections for which there is no evidence of presence or incubation at the time of admission. Patients with a HAI need longer to recover and have an increased probability to die. In the European Union alone, the estimated number of HAIs is 4.5 million annually, leading directly to around 37.000 deaths, 16 million extra days of hospital stay and 110.000 indirect deaths [7, 14]. The most effective counteractive measure to HAIs remains proper hand hygiene by health care workers [1]. It is estimated, that 20-30% of HAIs could be prevented by better hand hygiene compliance [7, 14].

The problem of hand hygiene in hospitals is a complex issue with two main aspects: (1) proper training in the cleaning technique and (2) compliance with desinfection procedures [15]. In recent years several applications to improve education of the hand cleaning technique have been implemented and tested in the field [10]. However, since health care workers wash their hands in less than 50% of the appropriate moments [23], the main issue is behavioral. Therefore, it is of interest to explore new approaches of improving health care workers' hand hygiene behavior. Thompson, Debbe, et al. found that theoretically based serious games can be effective at achieving behavioral change in both diet and physical activity [13].

In this paper, we describe the design of a serious game for the Microsoft HoloLens with the purpose of improving hand hygiene compliance. We have built a first prototype of an Augmented Reality application named CatCare. We decided to use Augmented Reality in order to make the users relate their actions and the lesson of the game to the real world and thus have implemented the application on the Microsoft HoloLens. The Hololens is capable of markerless tracking and therefore does not require a set up procedure before users can play with it. In CatCare, the user needs to take care of sick cats by feeding them. Whenever the user touches a cat, his hands become visibly contaminated and he needs to wash them before touching another cat. If the user fails to do proper hand hygiene, other cats will get infected and the user looses the game. The application is still research in progress. However, three implementation iterations with evaluations have already been conducted. We contribute to the field of serious games and gamification for health care education by presenting design objectives gathered from the scientific literature and learnings that have emerged throughout the development of the application.

2 Research method

In order to design a serious game to educate and motivate health care workers, patients and visitors in health care facilities, our research applies the design science research method (DSRM) [22]. We follow the methodological steps described by Peffers [22] involving the following activities: (1) problem identification and motivation, (2) definition of the objectives for a solution, (3) design and development, (4) demonstration, (5) evaluation and (6) communication. In this article, we apply this methodology as follows: In the introduction section we motivate (1) the problem of hand hygiene compliance and define the central solution objective of the artifact. After reviewing the literature associated with the problem, we derive requirements for the artifact (2). Based on the background literature we develop an artifact iteratively (3). We demonstrate (4) the artifact's evolution and the design knowledge that was gained through iterative testing. The artifact was evaluated (5) in several stages of its evolution via questionaires and interviews. This article fulfills the purpose of communicating the results (6).

3 Related work

CatCare was implemented with WHO five moments as educational basis. The WHO five moments is a simple conceptual framework for when hand hygiene should be performed is are used as the basis for professional medical education [9].

Researchers have drawn upon psychological theory to explain the lack of hand hygiene compliance. Kretzer & Larson [4] found that beliefs, perceived health threat, cues, self-efficacy and attitude influence hand hygiene behavior. In order

to increase health care worker's perceived threat we used Augmented Reality so the user sees virtual germs on his hands and surroundings.

Kretzer & Larson [4] also found consistent evidence, that self-efficacy is associated with behavioral change and that interventions targeting behavioral change should include the concept of self-efficacy [4]. Self-efficiacy can be influenced in various ways. In the past serious games have been used to increase self-efficiacy in various health care domains [13, 12, 11], such as diabetis and HIV prevention.

In recent years researchers have started to use gamification and serious games as interventions to improve hand hygiene compliance. Sanchez et al. [8] did a literature review on gamification but only identified four games related to hand hygiene.

Vazquez et al. [16] built a simulation, where users have to decide when and how they must perform hand hygiene. However, their simulation does not simulate a stressful situation as health care professionals experience throughout their daily routine. Marques et al. [18] used a gamification approach in a health care facility. Their system tracks the nurses' actions and awards points for good hand hygiene behavior but does not focus on facilitating the education of health care workers.

Galluzi et al. and Kutafina et al. [17, 10] focus on teaching proper hand washing technique via gamification but do not teach in which situations hand hygiene is necessary.

3.1 Design objectives based on the literature

The factors that lead to poor hand hygiene compliance of individual health care workers have been researched extensively. Risk factors for hand hygiene compliance include understaffing, bad role models and working in an intensive care unit. Moreover, male health care workers and physicians are more likely to have low hand hygiene adherance (compared to nurses) [1, 7].

Many studies highlight that education is a cornerstone for improvement with handhygiene practices but there are limitations such as financial constraints or lack of teaching experience [1, 7]. Moreover, education has been found to be most effective, when it includes workshops, bedside teaching, and simulation-based training [7]. Therefore, in order to create a simulation that resembles the real world struggle in which health care workers need to do proper hand hygiene while having to treat many patients, we propose that the artifact should simulate a stressful activity that needs to be accomplished, while the user needs to perform proper hand hygiene.

Additionally, the artifact should be easily accessible to health care workers. it should not require prior knowledge, complicated setup procedures or a special infrastructure. Moreover, it should be easy to fit into the time schedule of health care workers. From this reasoning we argue that the artifact should be easily accessible to health care workers.

Furthermore, high-quality and timely feedback on hand hygiene behavior is important to raise the awareness of health care workers [7, 5]. Being caught red handed makes it easier for people to remember their actions that lead to the

mistake. Moreover, if nobody sees the mistake and judges, it might be more likely to achieve a mindshift and behavioral change. Therefore the user should get instant feedback when he does a severe hygiene mistake.

4 Artifact Design

To study hand hygiene compliance in a serious game context, we developed CatCare. Since it was developed iteratively some parts of it have changed over time. We will now briefly describe the latest version (version 3) of CatCare:

Figure 1 shows an overview of the holograms the user sees augmented in to his surroundings while playing CatCare. On the far right of the figure is the sink. The two beds with the sick cats are to the left of the sink. The food bowl is on the counter with the green symbol on the left and the water bowl is on the counter with the blue water drop. There are five cats wandering around on each bed. The cats on one bed have a different disease than the cats on the other bed and need to be held in quarantine from each other. The user can see that the cats are sick by coloured particles radiating around the cats. The cats on the first bed have green particles and the cats on the other bed have red particles. Over time a cat will become thirsty or hungry. The user then needs to pick up the cat and carry it to the food or the water bowl. Once the cat is done with eating or drinking, the user needs to carry it back to its bed. If the cats are not nurished within a certain period of time, they will starve and the game is over. Whenever the user picks up a cat, his virtual hands will get contaminated with the cat's disease. The virtual hand will then also have radiating color particles around it. The user can decontaminate his hands by clicking on the virtual sink. The virtual hands will then instantly become clean again. If the user transmits a disease to a kitten it dies and the game is over. Therefore, in order to win the game, the user needs to make sure the cats get their food in time, while he does proper hand hygiene in order to prevent transmitting a desease. So far, three iterations of the game have been implemented. Each iteration was evaluated using the System Usabilty Scale (SUS) and open questions for feedback. The first iteration was tested by 39 users and had a SUS of 71.5, the second iteration by 9 users (SUS: 74.1) and the third iteration by 14 users (SUS: 73.9)

Next we will discuss the differences between the three iterations of CatCare, why they were made and what conclusions we derived from them.

5 Discussion

Regarding existing design principles, there is a consensus in the scientific literature on serious gaming and gamification that games need to be fun for the user [21]. However, the use of gamification and serious game design principles in mHealth applications is yet a burgeoning innovations practice [20]. In order to make our application fun to use, we tested different game elements and regularly tested the usability of our application. To make design decisions we relied

on observations, verbal comments from the users, results of the SUS and written comments in the open ended comment section we added to the SUS.

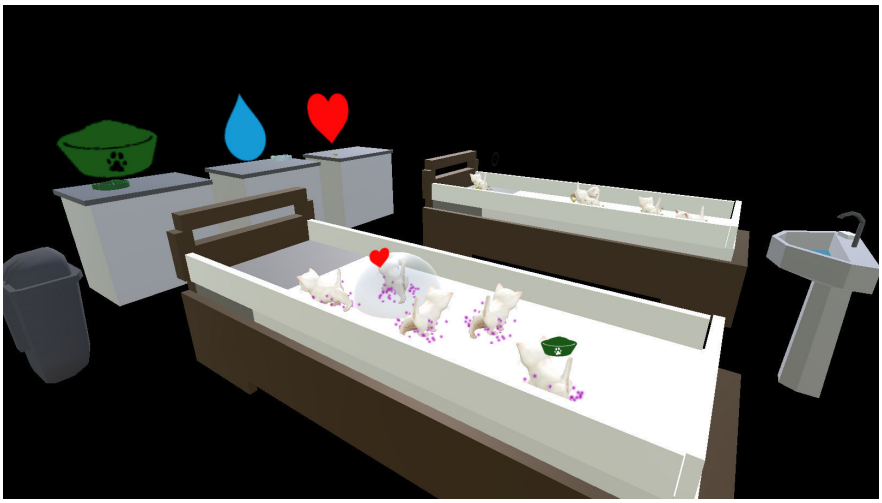

Fig. 1. This figure shows an overview of the holograms the user will see augmented in to his surroundings.

In version 1 we were using a virtual arrow to help the user learn the game. The arrow followed the naive strategy depicted in figure 2 without optimizations. However, during test we soon observed that users were ignoring the arrow and only started using it once we told them to use it. Moreover, they would then just click on whatever the arrow was pointing at without reflecting upon their actions. In version 2 we therefore read them written instructions explaining the setup and the goals of the game without using the arrow. Users then found optimizations to the naive strategy much faster and also seemed much more engaged in the game.

In versions 1 & 2 there was only one level and users often found that the game was not challenging enough. Two users wrote they would have liked "more difficulty, more variation" and "more complexity". Therefore, in version 3 we implemented four different levels so the users could adjust the difficulty to their preferences. Figure 2 shows a flow diagram of the game and table 1 shows an overview of the different levels of CatCare. When we tested the application with users we found that users seemed more engaged and tried out different levels, until they found a level that was appropriately challenging for them.

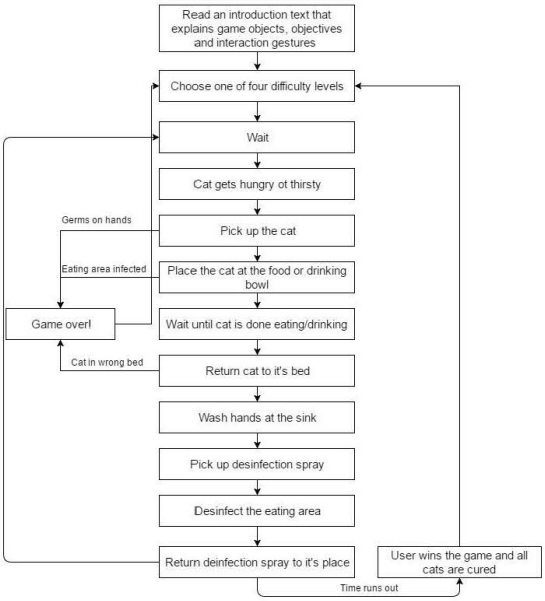

Fig. 2. This figure shows a flowchart of the CatCare application

6 Evaluation

There is no standard for measuring compliance with hand hygiene practices. [19] The three most frequently reported methods of measuring compliance are direct observation of practice, self-report of healthcare workers and indirect calculation based on hand hygiene product usage or electronic monitoring devices [19].

We are planning to evaluate CatCare with health care workers in a health care facility. We will let each health care worker in a ward play CatCare for half an hour following a standardized procedure. The treatment will be repeated every two weeks. Over the course of the intervention and the three succeeding months we will measure the desinfection fluid consumption in the ward and a second ward that we will treat as the control group. Consumption of hand-rub desinfection fluid is an accepted dependant variable of hand hygiene compliance [1].

7 Conclusion and potential contribution

Lack of hand hygiene compliance in health care facilities is a serious problem. Serious games have been used in other health care domains to achieve behavioral change. In this paper, we utilize a design science approach to design, develop and evaluate our serious game artifact. We are developing an Augmented Reality serious game called CatCare that could be used for health care worker's hand

Table 1. Differences between the levels

Level 1 (easy): One cat will randomly get thirsty every 40 seconds and the user has 40 seconds time to give water to the cat before it dies.
Level 2 (medium): Cats can get hungry or thirsty. One cat will randomly get hungry or thirsty every 30 seconds. Cats die if the user does not treat them within 30 seconds
Level 3 (hard): Hunger or thirst will appear every 20 seconds. Cats die if the user does not treat them within 30 seconds
Level 4 (extreme): Hunger or thirst will appear every 15 seconds and the germs become invisible. Cats die if the user does not treat them within 30 seconds

hygiene education. The novelty of our approach lies in the idea to employ a serious game that has parallels to health care workers daily routine. By using Augmented Reality, we enable the users of CatCare to see where germs are and how they are transmitted on to health care worker's hands. By focusing the user's attention to tending cats, we simulate the time pressure and stress that health care workers perceive in their everyday life and diverts them from doing proper hand hygiene. Since CatCare provides instant feedback when hand hygiene errors are made, users can test methods for themselves that will help them perform proper hand hygiene under stress.

We have described how we are planning to evaluate the application. If we can show that the application improves hand hygiene behavior of health care workers, the application could be used as a tool in the education of health care workers. Maybe it could also be used in regular intervals to refresh the hand hygiene motivation and knowledge of health care workers. If we can show that people without prior knowledge of hand hygiene can learn hand hygiene from the artifact, it could be used to make hospital visitors aware of HAIs.

Our work contributes to the literature on hand hygiene compliance by exploring a new design-oriented intervention. Finally, we contribute to the field of health care education by presenting design objectives for serious games derived from the scientific literature and learnings from implementing them into an artifact.

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