

VIRTUE - a virtual reality trainer for hand hygiene

1st Lauren Clack

Infectious Diseases & Hosp. Epidemiology
University Hospital Zurich
Zurich, Switzerland
lauren.clack@usz.ch

2nd Christian Hirt

Innovation Center Virtual Reality
ETH Zurich
Zurich, Switzerland
hirtc@iwf.mavt.ethz.ch

3rd Marcel Wenger

Health Innovation Center
University Hosp. Zurich
Zurich, Switzerland
marcel.wenger@usz.ch

4th Dirk Saleschus

Infectious Diseases & Hosp. Epidemiology
University Hospital Zurich
Zurich, Switzerland
dirk.saleschus@usz.ch

5th Andreas Kunz

Innovation Center Virtual Reality
ETH Zurich
Zurich, Switzerland
kunz@iwf.mavt.ethz.ch

6th Hugo Sax

Infectious Diseases & Hosp. Epidemiology
University Hospital Zurich
Zurich, Switzerland
hugo.sax@usz.ch

Abstract—Hand hygiene is an important measure to prevent healthcare-associated infections. However, healthcare provider adherence to hand hygiene remains low. Due to the invisible nature of microorganisms and delayed expression of healthcare associated infections, healthcare providers are rarely aware of transmission dynamics and they don't receive feedback about the consequences of missed hand hygiene. This situation makes it difficult to associate unsafe behaviors with their negative consequences. We introduce the concept of an experiential virtual training environment for hand hygiene, where feedback about microorganism transmission and infectious outcomes are introduced visually, thereby enhancing associative learning and increasing intrinsic motivation to perform hand hygiene.

Index Terms—hand hygiene, virtual reality, training

I. INTRODUCTION

Healthcare providers (HCPs) are responsible for both assuring patient care and preventing negative patient outcomes. Healthcare-associated infections (HAI) acquired during care are the most frequent adverse event in healthcare delivery, affecting billions of patients worldwide [1]. Encouragingly, a significant proportion of HAIs can be prevented through the application of evidence-based infection prevention measures. Hand hygiene (HH), for example, is recognized as a measure to limit transmission of microorganisms and to prevent HAI [2]. Despite its proven efficacy, studies report low HCP adherence to HH, often in the ranges of 40% [3]. Improving HCP adherence to HH is therefore a global priority.

To achieve this goal, we develop a virtual healthcare environment for training HH behaviors. Establishing such a training environment offers several benefits. Namely, the virtual environment (VE) can be altered in ways that would be otherwise impossible in the real world (e.g. displaying microorganism transmission, time-warping). The VE also offers a controlled study environment in which variables (e.g. patient behavior, social environment, and stressors) can be controlled, making it ideal for studying influences on behavior. Finally, the behaviors of the HCP in this VE can be automatically captured and analyzed, eliminating the need for costly and time-consuming observations. Thus, the VE has potential as

a powerful tool for both training and studying HCP infection prevention behaviors [4].

II. RELATED WORK

Many infection prevention efforts involve HCP education about when and how HH should be conducted according to established guidelines [5]. Applications using serious gaming [6] and virtual reality [7] for teaching HH guidelines have also been reported. Yet, these rule-based approaches have often failed to achieve significant or sustained improvement in HH behaviours, likely because they fail to address barriers in the environmental context and do not elicit the motivation necessary to reliably change HCP behavior [8].

We aim to overcome limitations of existing interventions by creating a VE in which HCP behaviour can be trained experientially. Specifically, the VE goes beyond previous interventions by (i) providing visual feedback about microorganism transmission and infectious outcomes to encourage experiential learning, (ii) allowing real walking within the virtual training environment, and (iii) creating a multi-user environment to explore social influences on HH.

III. VIRTUAL REALITY TRAINER FOR HAND HYGIENE

Given that a VE for experiential HH training has - to the best of our knowledge - yet to be established, several technical and behavioral research questions emerge:

- Due to the invisible nature of microorganisms, HCPs are largely unaware of the contamination of objects and do not receive feedback about how their own manipulations result in propagation of harmful microorganisms. How can microorganism transmission be visualized such that HCPs experience learning, linking their HH behavior with visual contamination of the VE?
- HAIs can only be detected with a significant delay and it is nearly impossible to trace these back to a specific behavior. Thus, HCPs are rarely informed about the consequences of missed HH opportunities. How can infectious outcomes be optimally portrayed in the VE such

that HCPs understand to link missed HH opportunities with negative patient outcomes?

- Users should experience sufficient presence in the VE, such that they behave as they would in the real world. What level of context (i.e. realistic setting and storytelling) and immersion (i.e. high technical quality of interaction) are necessary to ensure high enough levels of presence such that participating HCPs react to visual stimuli as they would in the real healthcare environment?
- To what extent do virtual stimuli (i.e. germ visualization and time warping) influence HCPs' HH behavior in the VE? How effectively and sustainably can HH behavior be trained in the VE? Can it be carried over to improved HH performance in the real world?
- Existing VR systems allow navigating the VE through handheld controllers using a teleporting functionality. Will the addition of real walking in a VE improve the immersion and thus the overall learning progress?
- Many healthcare activities are performed within a clinical team and the social environment has an important influence on HH behaviors. How could real walking be combined with multiple users located (i) in different physical spaces i.e. for net-based collaboration, or (ii) in the same physical space (i.e. colocated)?

A. Microorganism visualization and time-warping

Technically, the transmission of virtual microorganisms is visualized in the VE by tracking the physical location of the users hands with the controllers and producing a colored overlay that maps onto the VE whenever virtual microorganisms are transmitted by his hands. When the virtual patient becomes contaminated, a time-warping animation is initiated in which virtual time runs much faster than the real one. Thus, long-term effects on the patient are visualized (e.g. by getting pale, haggard face, etc.), but even more dramatic effects could be explored to demonstrate the down-the-line patient consequences of insufficient HH. We have developed a basic care scenario in which the participating HCP enters the virtual patient room with handrub dispensers, shakes the scripted virtual patients hand, and auscultates the patient with a stethoscope before exiting the room (Fig. 1).

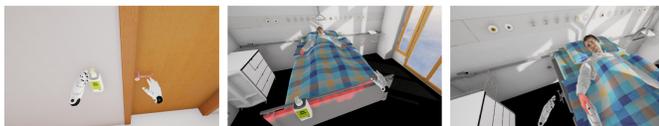


Fig. 1. Spreading of germs by insufficient HH (red regions).

B. Real Walking

An accurate perception of space is important for HCPs, who have to judge the time needed to walk distances during critical care situations. Real walking is also the only way to appreciate the challenge of navigating narrow and crowded patient rooms. To allow real walking in the VE, we use an IS-1200 optical inside-out tracking system, which covers a tracking space of

12x6 meters, allowing walking between two adjacent patient rooms to further increase realism and immersion.

C. Multiple Users

Many healthcare activities are performed by multiple HCPs simultaneously and the presence of colleagues influences behavior. To enable multi-user interaction, we portray additional users as avatars in the VE.

D. Capturing User Interaction

A benefit of VE training is that individual user behaviors can be automatically captured and analyzed, without the need for time-consuming visual observations. This allows for providing detailed individual feedback, e.g. about transmission hotspots.

E. Integration of Stressors

To increase user presence and ensure that the VE resembles actual working conditions, we incorporate stressors, such as medical monitoring devices beeping, interruptions from colleagues or patients, etc. Such stressors divert attention away from the primary task to modulate the training difficulty.

IV. SUMMARY AND FUTURE WORK

We described a virtual HH trainer, which has the potential to increase HCPs' HH performance by reintroducing an otherwise missing feedback about consequences of unsafe behavior and therefore to increase HCPs' motivation to perform HH. After assessing the impact of virtual HH training on HCP behavior, future work will extend the system to other healthcare settings and situations in which improving HH is a priority.

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