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Using Virtual Worlds to Train Healthcare Workers - A Case Study Using Second Life to Improve the Safety of Inpatient Transfers

***Ann Merete Duedal Jensen*[1]*, Merete Martlev Jensen*[1]*, Anne Sofie Korsager*[1]*, Mei-Sing Ong*[2]*, Farah Magrabi*[2]*, and Enrico Coiera*[2]**

[1] *Medical Informatics Group, Department of Health Science and Technology, Aalborg University, Aalborg, Denmark*

[2] *Centre for Health Informatics, Australian Institute for Health Innovation, University of New South Wales, Sydney, Australia*

Abstract

Virtual worlds such as Second Life may offer a new environment to deliver simulation-based safety training to clinicians. The objective of this study was to design and implement a simulation of inpatient transfers in the virtual world of Second Life, and to undertake a preliminary evaluation of its usability as an educational tool.

A simulation of inpatient transfer was developed using the Linden Scripting Language in Second Life. A virtual hospital was built and four scenarios of inpatient transfer varying in mode of transport (bed, trolley or wheelchair) and infection control precautions (no-infection, droplet, contact or airborne infection) were implemented.

System usability was assessed using a "think aloud" protocol in combination with surveys and interviews with 15 participants who found the simulation environment easy to use, and fit for purpose. The novelty of using a virtual world was regarded as an advantage over other training methods, as was the opportunity to learn and practice inpatient transfers while receiving instant feedback during the process. Participants agreed that simulation has potential to improve awareness about hand hygiene and prevent errors.

Second Life was able to support the development of a virtual environment for patient safety training. Results from preliminary usability tests indicate acceptance of the simulation environment. Further investigation is required to evaluate usability with a representative group and determine if training porters in a virtual world will reduce errors in the real world.

Keywords: Patient Transfer; Computer Simulation; Online Systems; Computer-Assisted Instruction/Methods; Virtual Systems

1 Introduction

In medical training, simulation is a technique that is widely used, where users can experiment with different scenarios and improve their skills in a safe environment prior to real-world patient handling [1-3]. Simulations are particularly useful for upgrading competence in handling uncommon but potentially fatal problems that require rapid and correct responses, without exposing a patient to risk [4]. Further, simulations provide an effective platform for active learning. Active learning, if properly implemented, can lead to increased motivation to learn, greater retention of knowledge, deeper understanding, and more positive attitudes towards the subject being taught [5].

Online environments or virtual worlds, which people inhabit with their own personal representations known as *avatars*, can be used to build highly realistic simulations of clinical environments for training purposes [6, 7]. The most popular is Linden Lab's Second Life, a commercial virtual world with more than 15 million registered users [8]. A recent review identified 11 healthcare related training sites in Second Life [8]. Ranked by traffic, the Ann Myers Medical Center, which offers training for medical and nursing students in taking initial medical history, physical exams and analysis of MRIs, CTs and X-rays, was the most visited site [8, 9]. Another example is the Imperial College simulation where students can get course credit by practising patient interviews, making a diagnosis, and providing treatment in a virtual respiratory ward [8]. Second Life is also being used in bioterrorism defence training [10], development of a virtual patient [11], and emergency preparedness training [12].

The objective of this paper was to design and implement a medical simulation of inpatient transfer in Second Life; and to conduct a preliminary evaluation of its usability. Inpatient transfer is associated with many risks, adverse events are reported to occur in 6% to 66% of transfers, and is associated with longer hospital stays and increased mortality [13]. An Australian study which examined human factors in patient safety incidents associated with transfers found that personnel were not adequately trained [14], suggesting that better transport planning and training personnel in patient safety procedures can reduce adverse events [15, 16]. In a recent study on inpatient transfers to Radiology carried out by the authors (MO, EC), it was found that transport protocols such as adherence to infection control precautions and the use of appropriate transport vehicle were often not complied with, exposing patients to unnecessary risks [17].

In this study, we explore the feasibility of using a virtual hospital to model safety scenarios for inpatient transfer, and evaluate the potential of Second Life to build clinical simulations as educational tools. To this end, we developed a model for training hospital porters, with an emphasis placed on using the appropriate transport vehicle and complying with infection control precautions during transfer. We envisage that the model can potentially be employed to better inform hospital porters about the transport protocols, thereby improving adherence.

2 Methods

2.1 Setting

Our simulation was based on a previous observational study on inpatient transfers to Radiology at a 440-bed teaching institution [17]. A model of the observed transfer process was developed. A transfer begins when the Radiology coordinator instructs a porter to transfer a patient. A transfer form is given to the porter, containing information about the patient any transport requirements, including mode of transport (portable bed, trolley and wheelchair) and infection control precautions (no infection, droplet, contact or airborne infection). The porter then retrieves the patient using the stated transport vehicle. When handling a patient, appropriate infection control precautions must be adhered to, depending on the types of infection. Standard precautions include the use of gloves and gowns and the practice of hand hygiene. For patients with airborne infection, the use of mask is additionally required. Figures 1 and 2 detail the transfer process from the ward to Radiology and the return journey respectively.

Four specific transfer scenarios were simulated for training purposes based on the type of transport vehicle and infection control precautions: (1) transfer in bed, no infection; (2) transfer in trolley, contact precautions; (3) transfer in bed, droplet precautions; and (4) transfer in wheelchair, airborne precautions.

2.2 Development of the Simulation Environment

The simulation was developed in the virtual world of Second Life, which enables building 3D objects and provides a programming language, called the Linden Scripting Language to generate active behaviors with the following features:

Building environment: A premium membership was used to purchase 4,048m^2 of land at auction, allowing 900 building blocks, also known as primitives. A user group was formed to allow multiple avatars to concurrently build objects on the same parcel. A virtual hospital with two wards and a Radiology department was built by linking floor, wall, and ceiling primitives using the avatar build menu in Second Life. The transfer process required creation of multiple objects and actors:

Actors: Porters must interact with nurses, a radiology coordinator and a patient. Three nurses and one radiology coordinator were built as images from snapshots of avatars that were processed in an external drawing program, uploaded into Second Life and placed on transparent 2D objects. Two patients were based on existing

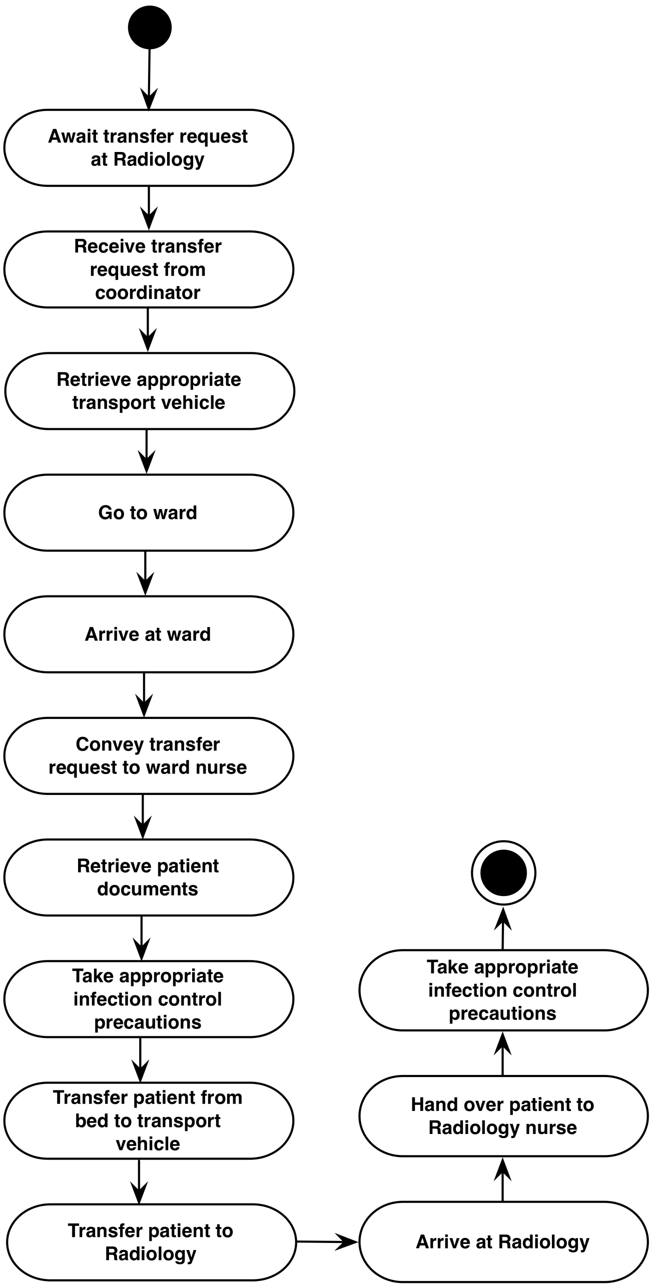

Figure 1: Patient transfer process from ward to Radiology [after 17]. *"Take appropriate infection pre-cautions" includes washing hands, wearing or removing gloves, mask, coat and/or eyewear, and cleaning trolley or wheelchair.*

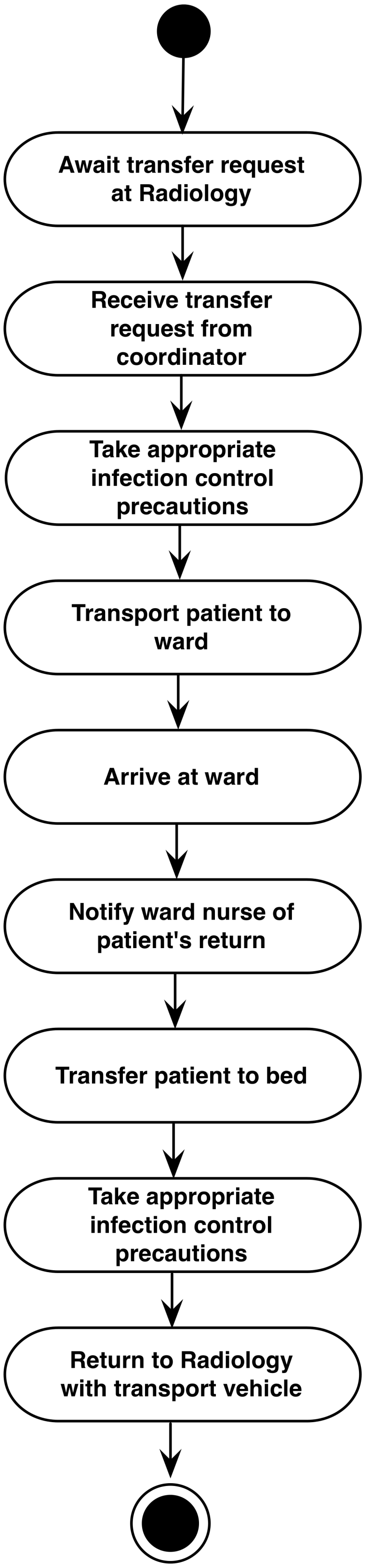

Figure 2: Patient transfer process from Radiology to ward [after 17].*

objects modified to suit our requirements.

Transport: Two portable beds, a trolley and a wheelchair required to transfer patients were bought and modified e.g. by adding wheels to beds.

Documents: Patient documents such as medical records and forms were created as objects with a texture front from images in an external drawing program and uploaded into Second Life.

Infection precautions: Protective equipment such as gloves, eyewear, masks, and/or coats were created as clothing objects because such textures cannot currently be scripted in Second Life. As with the patient documents, equipment were created with a texture and placed in dressers located within the wards. Three garbage bins were included to allow avatars to dispose of used protective equipment. Sinks were provided for porters to wash their hands and three cleaning agents were built to clean the trolleys and wheelchairs.

2.3 Programming Object Behaviors and User Feedback

The Linden Scripting Language was used to develop active behavior and communication of objects in response to user actions during the simulation. These included transferring a patient in a bed, trolley or wheelchair, wearing and removing protective equipment, cleaning hands and the mode of transport, retrieving patient documents, and interacting with personnel. To interact with an object in Second Life users (via an avatar) must click on them with a mouse. Objects also needed to keep track of the sequence in which an avatar performed the actions required to transfer a patient. To ensure that actions were performed in the right order listeners were implemented in all objects to trigger events depending on the content of messages received. During simulation avatars received feedback via an on-screen message in response to an action required by a scenario. At the end of the scenario feedback about the time taken, number and types of errors is provided.

2.4 Usability test

Participants: To evaluate the usability of the simulation, students and staff members from the Centre for Health Informatics, University of New South Wales were recruited (n=15). The number of participants is adequate to fully test the simulation for further evaluation with a representative cohort of end-users [18].

Methods: The Think Aloud method was used to evaluate users' experience with the simulation. The method involves participants thinking aloud as they perform the specified tasks, thus providing rich verbal data about the participants' reasoning process [19]. Additionally, a post-test questionnaire and interview were used to evaluate usability of the simulation. A structured questionnaire was designed based on recommendations provided by Kalawsky et al for evaluating the usability of virtual environment systems [20]. Five aspects of the system were assessed using a 6-point likert scale: (1) functionality; (2) simulation fidelity; (3) learnability; (4) user guidance and help; and (5) sense of immersion/presence. The interview was semi-structured with seven open-ended questions (Table 1).

#	Question
1.	What do you like about the system?
2.	What do you not like about the system?
3.	What was easy to use or understand?
4.	What was difficult to use or understand?
5.	What would you change about the system?
6.	What is your overall impression of the system?
7.	Do you have other comments or questions about the system or your experience with it?

Table 1: Interview Questions

Usability testing procedure: Within a computer laboratory, participants were individually given a tutorial about Second Life and asked to perform two of the following randomly assigned patient transfer scenarios while thinking aloud about the specified tasks, as regards to where they were going, what they were looking for and areas of frustration: 1) Patient is transferred in bed – no infection precautions; 2) Patient is transferred in wheelchair – airborne infection; 3) Patient is transferred in trolley- contact infection; 4) Patient is transferred in bed– droplet infection.

Users interacted with objects by clicking on them, on-screen text messages were used to communicate with personnel and receive feedback on their actions. At the end, users were given feedback about the time taken, number and types of errors. As participants were unfamiliar with the patient transfer process cue cards were provided and the facilitator only interfered when they failed to progress or stopped thinking aloud. After testing participants were asked to complete the questionnaire and were interviewed.

3 Results

3.1 Development of the Simulation Environment

It was possible to develop a simulation environment in Second Life consisting of a virtual hospital with two wards and a Radiology department including furniture,

Figure 3: An aerial view of the virtual hospital; an avatar wearing a mask used if the patient has an airborne or droplet infection; an avatar transferring a patient in bed.

medical equipment, personnel and patients (Figure 3; available from http://snurl.com/svnog.). All four patient transfer scenarios were implemented. The simulation environment supported one user at a time using a specific avatar. Users were required to perform all actions in the correct order to successfully complete a scenario.

3.2 Results of Usability Test

All 15 participants completed the training, simulation, questionnaire and interview. On average, the training session and usability test lasted for 6 minutes and 41 minutes respectively. Nine of the participants were males and the mean age was 32 (range 23-52). Of the participants, four had no academic degree, two Bachelors, three Masters, and six PhD degrees in a field related to health informatics. Two of the participants were clinically trained, the remaining did not have any health work experience. Twelve of the 15 participants had heard of Second Life before participating in the test, and three had tried to use it.

Findings from Questionnaire: Responses to the structured questionnaire indicated acceptance of the medical simulation environment (Table 2).

Functionality: Participants agreed that the system was easy to use; they were impressed with the environment but reported some difficulties in selecting and interacting with objects.

Simulation fidelity: Overall, participants agreed that they could easily locate objects, although some found it difficult to find their way around the hospital.

Learnability: Views about learning were mixed; although there was a lot to learn, most participants thought it was easy to learn, with two-thirds of the participants found that the second test session was easier to complete. They reported enjoying the opportunity to use an avatar for training.

User guidance and help: While participants reported being aware of feedback provided by the simulation, they found that signs and text feedback were not always noticeable and understandable.

Sense of immersion / presence: Participants agreed that the virtual environment was realistic and fit for purpose. Most were confident about using the simulation.

Findings from Think Aloud Protocol and Interviews: The Think Aloud Protocol and post-test interviews with the participants revealed several usability issues and areas where potential improvement can be made to the simulation. Firstly, some participants found it difficult to control an avatar in Second Life, due to unfamiliarity with using the arrow keys. This could be remedied by providing control using a mouse or joystick. Secondly, many participants were distracted by the walls of the hospital when attempting to separate the multiple views available to an avatar. Further, participants found it unrealistic that the avatar did not need to be close to objects when interacting with them (e.g. washing hands at a sink) and wanted a busier hospital with more people, animations of objects and activities. Some wanted more background sounds as well e.g. nurses speaking. Few participants believed Second Life by itself was too slow and characterized the graphics as being poor.

Nonetheless, all participants expressed that the novelty of using a virtual world for training was an advantage over other training methods, as was the opportunity practice patient transfers while receiving instant feedback during the process. Participants believed that the simulation had potential to improve awareness about hand hygiene to prevent errors.

4 Discussion

4.1 Feasibility of simulating patient transfers in a virtual world

Main findings and implications: We successfully designed and built a simulation of patient transfers for safety training in Second Life, a commercial virtual world. A hospital with two wards and a Radiology department was constructed to implement four scenarios of patient transfer. The hospital is equipped with patients, nurses, a Radiology Coordinator, medical equipment and furniture. A simulation of the patient transfers in a virtual world means that the process can be learnt and practiced in a safe environment. The ability to provide instant feedback is important because it supports performance and motivation by informing users about their actions, any errors, and allows correction [6, 21, 22].

The simulation is available online and requires installation of the Second Life software. Many simple tools such as remade primitive shapes make it easy to build simple structures, and add features to make the objects realistic (e.g. adding wind, gravity and light). Pictures, sounds and animations can also be uploaded to improve fidelity. Navigation, camera controls and menus are

Questionnaire Item	Number of responses (n=15) Likert Scale						
	1	2	3	4	5	6	N/A
Functionality							
I found the system easy to use	0	1	0	0	10	4	0
I was impressed by the way I could interact with the environment	0	1	0	2	8	4	0
I found it difficult to select bed, trolley and wheelchair in the virtual environment	5	5	1	2	2	0	0
I found it easy to control bed, trolley and wheelchair in the virtual environment	0	1	1	2	8	3	0
I found it difficult to interact with objects (e.g. nurse and sink) in the environment	8	3	1	1	0	2	0
Simulation fidelity							
I found the hospital environment unpleasant	4	7	1	0	2	1	0
Objects in the virtual environment were realistic	1	0	4	5	4	1	0
I found it difficult to find my way around the hospital	8	3	3	0	1	0	0
It was easy to find the things I was looking for	0	0	0	3	4	8	0
Objects in the virtual environment moved in a unnatural manner	2	3	3	1	4	2	0
Learnability							
I found it easy to learn how to use the environment	0	0	2	1	4	8	0
I needed to learn a lot of things before I could get going with the environment	5	4	3	2	1	0	0
I would imagine that most people would learn to use this environment quickly	0	0	1	1	5	8	0
I found the second scenario more easy than the first scenario	2	2	1	1	3	6	0
User guidance and help							
Information (signs and text feedback) was not noticeable	8	3	2	1	1	0	0
Information (signs and text feedback) was hard to understand	9	2	2	0	1	1	0
I was aware of making mistakes (If any mistakes were made)	1	1	2	4	5	1	1
Sense of immersion / presence							
I did not feel a sense of being immersed in the virtual environment	2	4	6	1	1	0	0
I got a sense of presence (e.g. being there)	0	2	0	4	7	2	0
I found it difficult to work in 3D	8	2	5	0	0	0	0
I can see a real benefit in this style of man-machine interface (for education/training)	0	0	1	0	5	9	0
I did not enjoy working with the system	8	7	0	0	0	0	0
I felt confident using the system	0	0	0	4	4	7	0

Table 2: 23 item questionnaire responses (n=15) on a 6-point Likert scale from 1 (strongly disagree) to 6 (strongly agree). Mode, median, range and sum for each statement are summarized [after [20]]

easily understood, and the programming language is simple (like programming in C).

Challenges in Second Life: One disadvantage of using a commercial virtual world such as Second Life is the restrictions and settings imposed by owners (i.e. Linden Lab). For example, an object cannot be attached before the avatar owns it or permission from the owner is given which is why we decided to use a dedicated avatar in our simulation, and this avatar was assigned ownership of the clothing items and dressers in the hospital. Knowledge of this avatar's name and password is required to access the simulation. Another restriction is that it is not possible to check another avatar's inventory, so we have no way of checking that the transfer form is kept by a porter while transferring a patient.

To recognize if an avatar is wearing protective equipment, clothing items must be programmed to detect and respond to actions. To workaround the inability to program textures, which are generally used for clothing items, we built clothing from primitives with attachments. As a result clothing built from objects does not follow an avatar's movements as naturally as textures. For example, the gloves we built from objects did not look as realistic as gloves made using textures. To make detailed clothes from primitives, an external 3D modeling program can be used to form an object and then upload it into Second Life.

The font and color of text used in the on-screen messages cannot be changed to make error messages more visible to users. Also options in the pie menu cannot be programmed, for instance the "Open" and "Drop" options in some scripts, affecting user friendliness as more mouse clicks and knowledge of menus is necessary to perform an activity.

Usability test: The simulation was positively received as indicated by questionnaire and interview responses. Although there were some difficulties in navigation and limitations of the environment were highlighted, the simulation was categorized as easy to learn and fit for purpose. All participants could see a benefit in using such a simulation environment for medical training.

4.2 Limitations and future work

This study has several limitations. Firstly, the simulation is based on one single process at a single institution and will require adaption for other settings. Only four scenarios of the transfer process are implemented, but all modes of transport and infection precautions are included in the model allowing extension to other scenarios. Second, we have evaluated the system on academics, rather than hospital porters. It is likely that the latter group does not have the same level of computer literacy, and may struggle to complete the training sessions.. However the objective of the present study was to examine the feasibility of the approach for further evaluation with a representative cohort of end-users [18]. If integrated with existing education, simulations may improve training for porters and thereby reduce errors in patient transfers. However it is unknown if training in a virtual world translates into actions in the real world [7]. Further investigation is required to determine the value of virtual training in improving safety in healthcare.

5 Conclusions

Medical simulation through Second Life appears to be a feasible method of providing virtual training to healthcare workers. This study is a proof-of-concept, and much improvement can still be made to create a more realistic simulation. Simulation is used extensively in industries that involve routine high risk activities. The use of simulation to improve patient safety in the medical environment clearly warrants further investigation.

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Correspondence

Dr. Farah Magrabi
Senior Research Fellow
Centre for Health Informatics
Australian Institute of Health Innovation
University of New South Wales
Sydney 2052 Australia

Phone: +61 2 9385 8694
Fax: +61 2 9385 8692

f.magrabi@unsw.edu.au