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Designing the User Interface of a Virtual Needle Insertion Trainer

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ABSTACT

In interventional radiology, inserting a needle to perform a biopsy requires a high haptic sensitivity. The traditional learning methods based on observation of skilled clinicians and training on real patients are questionable. Virtual Reality (VR) surgical simulators have previously been shown to be efficient for training. However, there is a lack of guidelines to ensure the fidelity of these simulators. In this paper, an iterative design approach is used to design and evaluate the user interface for a VR needle insertion trainer. Two experimental studies were conducted to evaluate some aspects of the system user interface. Results permit to validate some design choices and suggest future design directions to improve the interface and environment fidelity of the system.

Keywords

Simulator Fidelity; Interaction Design; Surgical Training; Haptic Perception; User Evaluation.

ACM Classification Keywords

H.1.2 [User/Machine Systems]: *Human factors;* H.5 [Information Interfaces and Presentation]: *Artificial, augmented, and virtual realities — Evaluation/methodology;* H.5.2 [User Interfaces]: *User-centered design — Haptic I/O — Evaluation/methodology*;

INTRODUCTION

Needle biopsy in interventional radiology consists of inserting a needle in the human's body to reach an endpoint, a target tissue or a specific zone, with a limited real-time visual feedback to guide the insertion. Accuracy when performing this procedure requires clinicians to have a high level of haptic sensitivity. This includes, for instance, detecting when the needle transpierces an organ or a tissue and being able to locate the needle tip inside the body. Therefore, the clinicians need to train their haptic perception skills to adapt to the complexity of this task. Commonly, novices are trained under the supervision of a strongly skilled clinician following Halsted's apprenticeship model for surgical training [26]. However, this model introduces ethical and patient safety issues since it uses patients as learning models [35]. Hence, practicing on a simulator can permit to reduce the risks for patients and can increase the efficiency of the haptic perception learning. There is growing evidence that simulation training increases adherence to best practices, improves clinical outcomes and reduces the costs associated with care [9].

In this context and as a consequence of the information technologies advances, new VR-based simulators have emerged to support learning surgical tasks and developing various skills. VR simulators have been shown to actually improve intraoperative skills in minimally invasive surgery [31,6,39,43]. Nevertheless, building an efficient VR surgical simulator depends on designing an effective interaction for this system. Indeed, complex and inappropriate user interfaces makes the simulator likely to be misused with frustrated learners maintaining their current training methods or not acquiring the targeted skills.

In this paper, we discuss the design of two aspects of the user interface for a needle insertion trainer: the interaction point and the user's viewing angle. The objective is to design and validate these aspects of the user interface based on a user centered design approach. This iterative approach permits to improve gradually the system by reducing its cost while ensuring that it fits the users' needs in terms of simulator fidelity and training objectives.

Simulator Fidelity

To design a system that overcomes the issues associated with VR trainers, it is important to ensure its fidelity. Fidelity of a simulation system is defined as the similarity between the knowledge taught in a simulator and the one used in the real world environment [36]. Previous research suggests that knowledge transfer is enhanced when the training and real world environments are closely matched [14].

Waller et al. distinguish between two types of fidelity – environmental fidelity and interface fidelity [41]. Environment fidelity mediates the mapping from the real world environment to the training environment. It is related to the realism of the environment and depends on

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a subjective judgment of similarity between the real and the simulated world. Interface fidelity, on the other hand, deals with the mapping of the variables in the training simulator to those in the trainee's mental representation of the word. It addresses the degree to which the input and output devices associated with the simulator work similarly to the way in which the trainee would interact with the real world. Drews and Bakdash indicate that interface fidelity is essential for skills transfer from the simulator to the real world [9].

Approaches to achieve simulator fidelity

There is a strong belief that the development of effective VR simulators is solely an engineering challenge. Indeed, much of the engineering approach is technology driven and has been focusing on high (visual) environment fidelity [9]. For instance, some studies have shown that novices prefer highly realistic simulations [30,33]. However, other studies show that the high realism alone is neither necessary nor sufficient for effective training [18,1]. Moreover, research indicate that complete environment fidelity and real word replication is something impossible to reach [13,34,36,17]. Finally, high-fidelity increases the cost of a simulation system [15].

The previous review indicates that the engineering approach toward high-fidelity simulators is questionable. On the other hand, there is a lack of guidelines or processes for how to go about achieving interaction fidelity and environment fidelity for surgical trainers. In fact, the levels of interface and environment fidelity required and the characteristics of the VR environment that are most important for effective training have not been defined. For instance, Salas et al. show that successful training using a VR-based simulator requires a minimal level of fidelity [28]. But how low should the fidelity of a simulator be in order to warrant the balance between a cost-effective and an efficient training system?

One possible approach to answer this question is the use of an iterative human-centered design methodology. In this approach, users are asked for their input on what aspects are important to them as well as which portions could be improved. The iterative nature of the process leads to gradual improvements of the system including the user interface [23]. This can permit to gradually achieve the required levels of fidelity while ensuring the cost-effectiveness of the simulator. There is currently a growing interest in using this method to design medical systems and surgical trainers [6,21,11,16,42,3,40].

In this work, we present the experience we had during the design of a VR needle insertion training system. The focus in this paper is put on the design of some aspects of the system user interface and the evaluation of their impact on fidelity based on users' subjective feedback. The findings of this preliminary study will then be used to improve the system following the iterative design approach principles.

RELATED WORK

Needle insertion tasks have previously been simulated using VR technology with a focus on training the learners' haptic sensitivity. For instance, Gerovich et al. [12], created a virtual system for needle insertion simulation where the user could see a four layers sample: skin, fat, muscle, and bone. The subjects could also feel the force feedback when performing the needle insertion using a haptic device. Their experiment shows that the visual feedback was efficient for training needle insertion into soft tissue. Bell and Cao [4] created a VR system by replicating an existing physical environment. By using a 6-DoF haptic device, they tested different types of force feedback for training a needle insertion task. Shin et al. [32] presented a needle insertion simulator using a haptic device, which provided realistic physical experience to medical students. This simulation was built with a 2-DoF haptic device and without a visual experience. Moreover, other simulators have been developed for training different biopsy and needle insertion procedures [6,25,37,38]. However, none of these systems did focus on the training of haptic sensitivity.

Despite the needle insertion task has widely been simulated using VR technology as shown in the previous review; none of these systems has been designed with a focus on the interface and environment fidelity of the simulator. This limits the use of these systems for training needle insertion tasks since none of them is currently adopted as a gold-standard for training biopsy procedures.

PREVIOUS DESIGN ITERATION

Following the iterative design methodology, a previous design iteration was conducted to build a first prototype of a needle insertion trainer. For that purpose, a task analysis of needle biopsy procedures was conducted using observation of video recordings of different biopsy procedures and on interviews with experts. This permitted to identify the learning objective of the needle insertion trainer and guided the design and the development of a first physical prototype [27]. The evaluation of this prototype demonstrated that it can be used for training haptic perception for the needle insertion task. However, experts' evaluation raised some limitations of the system. These limitations includes the shape and weight of the instrumented needle which were different from the actual biopsy needle, the limited reusability of the physical silicon tissues whose properties changed after few trials, the differences between the haptic properties of the silicon and the human organs, and the weakness of the needle tracking sensors which are very sensitive to the calibration phase and to the environment in which they are used. These issues negatively affected the training efficiency of the system. To overcome these issues, we are conducting a new design iteration to design a new VR-based system. In fact, VR is expected to overcome some of the previous issues by offering a more controlled training environment. In the following section, we discuss the design and development of this new VR trainer.

SYSTEM DESIGN AND DEVELOPMENT

Physical Interface

In order to overcome the issues associated with the instrumented needle, we designed a needle holder similar to the original biopsy needle (Figure 1), both regarding the shape and weight.

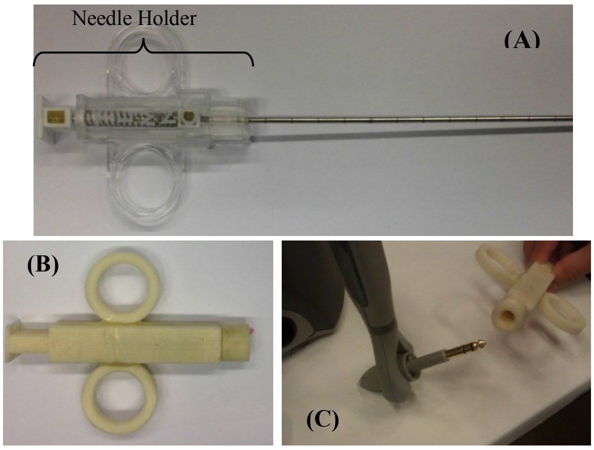

Figure 1: (A) Biopsy needle, (B) the new 3D needle holder, (C) connection of the 3D needle holder to a haptic device

In fact, previous studies have shown the importance of having identical instruments in the simulation and in the real-world to facilitate matching the psychological aspects of training to the clinical task [18,20]. For that purpose, the needle holder was faithfully reproduced using a 3D modeling software and printed using a 3D printer (Figure 1). The needle holder was then connected to a haptic device (Figure 1) in order to allow the user to manipulate a virtual needle and receive force feedback from the virtual environment.

Haptic feedback model

One important aspect for the environment fidelity is the haptic feedback. To bring realistic haptic feedback to the users and simulate needle penetration into soft tissue, a state-of-the-art previously validate model was used [2]. The model is based on a needle insertion inside a pig liver at a constant speed. Different model coefficients were assigned to reflect differences in tissue compliance.

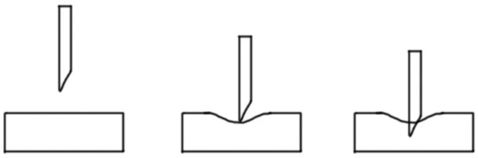

Figure 2: the three stages of needle-soft tissue interaction model

Using this model, the force feedback is calculated based on the needle position and tissue position and properties. This can be divided into three stages [19]. The first stage is a free-space movement of the needle before touching the tissue. The second stage is the needle-tissue viscoelastic interaction. It begins when the needle touches the tissue and ends when the deformed tissue surface is punctured. The last stage is the insertion through the tissue (Figure 2).

Graphical User Interface

Beside the physical interface that is directly manipulated by the user, additional objects were simulated. In fact, the virtual world is a replication of the previous physical prototype [27] and include a virtual needle and a virtual rectangular object simulating a soft tissue (penetrable surface) lying on a virtual table (impenetrable surface). The virtual needle is needed to give the user indications about the position and orientation of the needle in the virtual workspace and is controlled using the physical interface. Moreover, a virtual hand holding the virtual needle was added to increase the interface fidelity by giving more spatial cues to the users when manipulating the virtual needle. Furthermore, the cast shadows of the virtual needle and hand were also simulated to increase the spatial cues. In fact, previous studies have shown that the shadow is important to increase the depth perception and give spatial cues in VR surgical trainers [5]. Finally, the virtual camera was positioned at 45° to give the best viewing angle to the users. In fact, this position is similar to the clinician's point of view and permits to see at the same time, the top and side of the tissue while inserting the needle. These design choices will be discussed more in depth in the evaluation section. Figure 3 describes interactions between the components of the system.

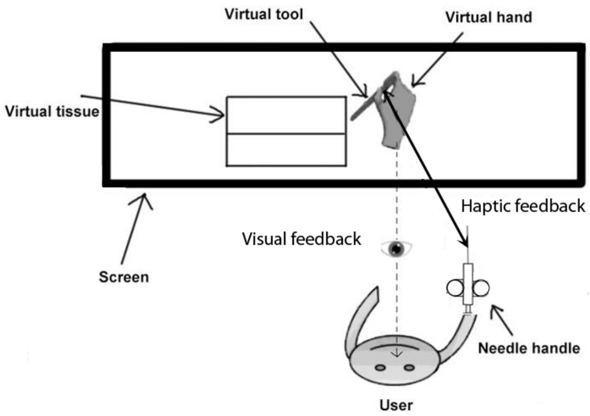

Figure 3: design of the system

System implementation

We consider that realistic haptic feedback and visual real-time tissue deformation are necessary components to ensure minimum environment fidelity for our simulator.

The virtual environment was created using CHAI 3D [8]. This open source framework was developed at Stanford University and is based on C++ programing. It is used for quick prototyping of applications that combine 3D modeling with force-feedback rendering capabilities. CHAI 3D was chosen as a development framework because of several advantages. First, it was successfully used for surgical simulation in the past [24]. Furthermore, it supports many commercial haptic interfaces, permitting a relative independence of the software from the device being used. Finally, it includes extension modules for simulating rigid and deformable bodies in real time.

Haptic feedback was displayed using a SensAble PHANTOM Omni haptic device and was implemented based on the previously described force feedback model. These haptic devices have 6-DOF positional sensing, 3-DOF force feedback, and a removable stylus for end-user customization. They have a workspace size of 160mm width x 120mm height x 70mm depth. This device was chosen because of its relative low cost and because it permits to render a sufficient amount of forces to simulate needle insertion into a human organ. The CHAI 3D GEL dynamics engine was used to simulate the deformation of the soft tissue during needle penetration. This engine uses a skeleton technique where filling spheres are inserted inside the mesh object and connected together using elastic links to model properties such as mass, inertia, elongation, flexion and torsion.

USER EVALUATION STUDY

Following the iterative design approach, we conducted two preliminary user studies to validate the design choices for two aspects of the prototype user interface.

Study 1: validation of the virtual interaction point

To increase the fidelity of the system, a virtual hand holding a virtual needle was used to represent the user's interaction point in the virtual environment. This simulates the first person perspective when manipulating the real needle. Thus, a non-animated virtual hand was attached to the virtual needle and both were attached to the haptic device. To validate this choice, it was compared to two other paradigms previously used in the literature (Figure 4): a virtual needle only (used for instance in [38]) and a virtual needle tip (used for instance in [4]). Our hypothesis is that the combination of the virtual hand and the needle would increase the realism of the virtual scene (environment fidelity) and the perceived accuracy of user when manipulating the needle (interface fidelity).

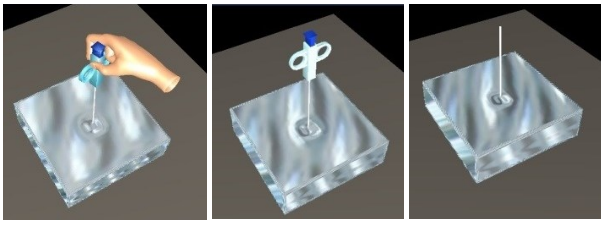

Figure 4: the three interaction points

Participants

Twelve healthy subjects, 10 males and 2 females, 24 to 38 years old participated in this experiment. Ten of them were right-handed. They were all students and staff from a research lab at a University. All of them reported a limited experience with haptics, virtual environments and needle insertion.

Experimental design

A within subjects design was used for this experiment meaning that all subjects performed the task with all modalities. The independent variable was the user interaction point with three levels (Figure 4): the virtual hand and needle (VHN), the virtual needle (VN), and the virtual needle tip (VNT).

Experimental setup

A 37 inches monitor was used to display the virtual environment. The monitor was positioned at 45° as shown on Figure 5.

To give subjects the possibility to compare the virtual and the physical system, we used also a physical setup composed of an actual biopsy needle, a silicon gel sample with similar compliance as the virtual tissue, and a wood table (Figure 5).

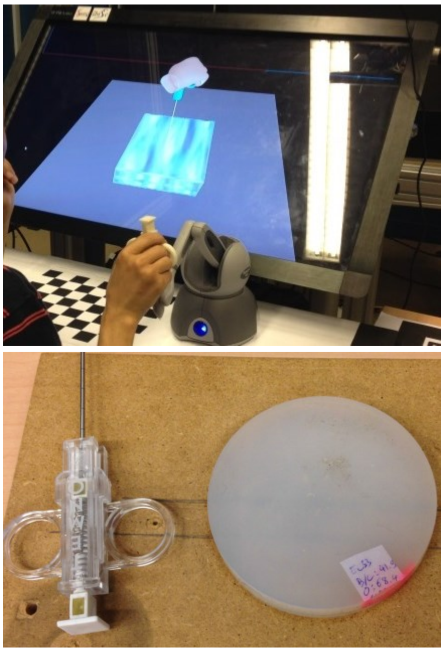

Figure 5: the experimental setup: (top) virtual system, (bottom) physical prototype

Task and procedure

The subjects were asked to insert the needle inside the tissue until reaching the table. There was no limited number of trials but the subjects were asked to repeat this task during two minutes. They were also allowed to choose freely the entry points into the (physical or virtual) tissue. At the beginning of the experiment, the participants were seated in front of the monitor and were asked to hold the haptic needle in a comfortable manner. They were then allowed to freely manipulate the needle and insert it inside the sample to become familiar with the system. After that, the actual experiment started.

The subjects were asked to perform the needle insertion task using the physical system (inserting the needle inside the silicone sample repeatedly during 2 minutes). Then, they were asked to repeat the same task in the virtual system for each of the three experimental conditions of the interaction point variable (2 minutes for each condition). The procedure is summarized on Table 1. The presentation order of the virtual system conditions (C1, C2 and C3) was counterbalanced to eliminate any learning effect. After completing all the trials, the subjects were asked to answer a questionnaire to give their feedback on the system they tested.

Table 1: experimental procedure

Familiarization with the virtual system	Test with the physical setup (1 trial during 2 min)	Test with the virtual setup (1 trial during 2 min for each condition)		
		C1	C2	C3

Data collection and analysis

A set of questions was asked with a focus on two components: the realism of each virtual setup as compared to the physical setup and the feeling of accuracy when performing the needle insertion task. These two aspects are related respectively to the environment and the interface fidelity of the system. A 5-point Likert scale was used for each question (Completely disagree/not satisfactory to completely agree/very satisfactory). Moreover, subjects were asked to rate the usefulness of the virtual hand in the virtual environment. As a further step in data collection and validation, the subjects were given the opportunity to comment on their experience with the system after session completion. The questionnaire answers were grouped and a mean rating score was calculated for each item. To compare the mean scores for each condition, the Kruskal Wallis test and Mann Whitney test were used (Non-parametric tests for ordinal data).

Results

The Kruskal Wallis test (Figure 6) showed no significant effect of the interaction point on the realism of the environment ($H_{(df=2)} = 0.122$, $p > 0.05$) while it showed a significant effect of the interaction point on the feeling of accuracy ($H_{(df=2)} = 21.13$, $p < 0.001$).

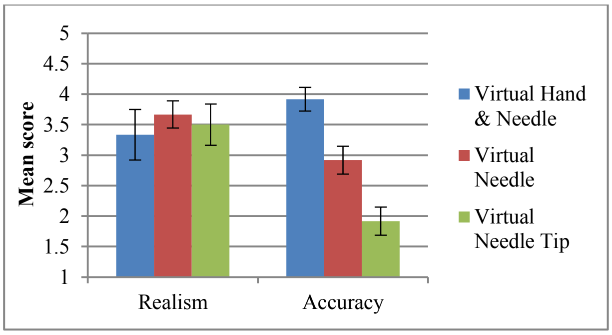

Figure 6: evaluation of the interaction point

The Mann Whitney test with Bonferroni correction (Table 2) showed a significant difference between the three conditions: the users felt more accurate when the virtual hand was used and felt less accurate when the needle tip was used (Figure 6). Finally, the subjects ranked the usefulness of the virtual hand high (A mean of 3.91 with 0.19 standard error).

Table 2: Mann Whitney test

Comparisons	U	Z	(p<0.05=significant)
(VHN, VN)	27.0	-2.75	**0.02***
(VN, VNT)	29.5	-2.57	**0.03***
(VHN, VNT)	4.5	-4.005	**< 0.001***

Experiment 2: evaluation of the user point of view

One critical question when designing virtual environments is to choose the users point of view and the 3D navigation technique. Different possibilities can be considered. For instance, the user can use the mouse and/or keyboard to manipulate the view point. However, this option was not appropriate for our system because the user is already holding the haptic needle in his/her dominant hand. Another option is to use a head tracking system so that the user could manipulate his viewpoint by moving his head. However, this option was eliminated because observations of users when interacting with the physical system showed that their head movements are limited. Moreover, observation of experts during the task analysis showed that they usually keep the same head position when manipulating the needle. Finally, a recent study has shown that head tracking can disturb the users when performing a surgical task on a virtual simulator [29]. This led to the design decision to setup a fixed point of view for the user, i.e. the user is not allowed to change his point of view during the task. The question is then what viewing angle of the virtual environment should be set in order to correctly perform the task? To answer this question, three angles were compared: A vertical angle of view (simulating a user looking at the tissue from the top), a horizontal point of view (simulating a user looking at the tissue from the side) and an inclined angle of view (simulating a user looking at the tissue at 45 degrees). The horizontal viewing angle corresponds to what one can experience when using a desktop computer and it is widely used in simulation systems. Moreover, the vertical viewing angle corresponds to what one can experience when using an interactive tabletops and was used for instance in [40]. It is to be noted that for all three conditions, the starting position of the virtual needle was vertical so that its displacements were always parallel to those of the haptic device handle. Our hypothesis is that the inclined viewing angle, allowing the users to see at the same time the side and top of tissue, would be the best suited for this task.

Participants

The same subjects that participated in experiment 1 were recruited for this experiment (the second experiment was conducted one day after the first experiment).

Experimental design

The experimental design was also similar to experiment 1. The independent variable for this experiment was the angle of view with three conditions: a vertical angle of view with the virtual camera positioned on top of the virtual environment and the monitor positioned in a horizontal position (0°

condition), an inclined angle of view with both the virtual camera and the monitor positioned at 45° (45° condition), and a horizontal point of view with the virtual camera positioned in front of the virtual environment and the monitor positioned in a vertical position (90° condition) as shown in (Figure 7).

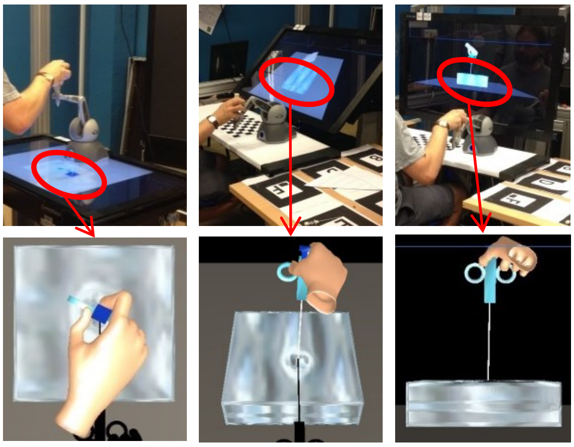

Figure 7: the three viewing angles: (left) vertical, (middle) inclined, (right) horizontal

Experimental setup

The same experimental setup as experiment 1 was used. The monitor orientation was changed each time, according to the experimental condition. Moreover, the haptic device was put on the monitor in the vertical angle condition to simplify the interaction and to avoid hiding the virtual workspace (Figure 7).

Task and procedure

The task and procedure were similar to experiment 1, except that there was no familiarization session, and that the three experimental conditions were different. At the end of the session, the subjects also answered a questionnaire to compare the three conditions.

Data collection and analysis

This time, the questions were focused on three components: the realism, the comfort and the accuracy. The first is related to the environment fidelity while the two others are related to the interface fidelity. A 5-point Likert scale was used for each question (Completely disagree/ not satisfactory to completely agree/ very satisfactory). Moreover, subjects were asked to rank the three viewing angles according to their preference. As a further step in data collection and validation, the subjects were given the opportunity to comment on their experience with the system after session completion. The same method as experiment 1 was used for data analysis.

Results

The Kruskal Wallis test (Figure 8) showed a significant effect of the viewing angle on the realism of the environment ($H_{(df=2)} = 7.99$, $p = 0.02$), the comfort of use ($H_{(df=2)} = 11.25$, $p = 0.004$), and on the feeling of accuracy ($H_{(df=2)} = 19.91$, $p < 0.001$).

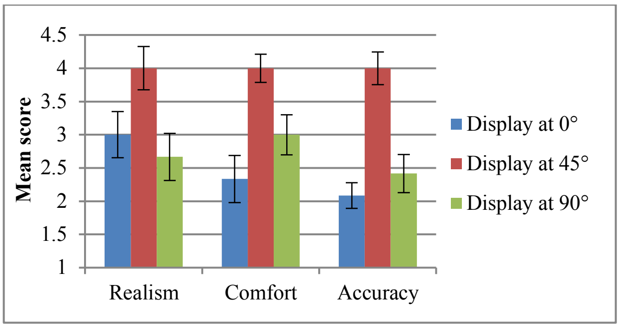

Figure 8: evaluation of the viewing angle

The Mann Whitney test with Bonferroni correction (Table 3) showed that the subjects found the environment more realistic and more comfortable and that they were more accurate with the inclined viewing angle. No significant differences were observed between the two other conditions. Finally, 91% of the subjects ranked the inclined angle as their preferred viewing angle, 66% of them ranked the horizontal point of view as their second choice, while 75% of them ranked the vertical point of view as their last choice.

Table 3: Mann Whitney test

	U	Z	(p<0.05 = significant)
		Realism	
(45°, 90°)	29.5	-2.52	**0.02***
(90°, 0°)	59	-0.774	0.439
(45°, 0°)	34.5	-2.25	**0.03***
		Comfort	
(45°, 90°)	31.5	-2.45	**0.01**
(90°, 0°)	50	-1.31	0.21
(45°, 0°)	21	-3.05	**0.006**
		Accuracy	
(45°, 90°)	6.0	-3.92	**0.000**
(90°, 0°)	59.0	-0.811	0.478
(45°, 0°)	18.0	-3.20	**0.003**

DISCUSSION

Designing efficient training simulators is a challenging task. In fact, they need to ensure the training of the correct skills and to have an appropriate interface and environment fidelity. The iterative design methodology is a valuable approach to design systems that fits best these requirements. In this paper, we used this method to design and develop a new VR-based training system for needle insertion. This design approach permitted to make some design choices regarding some aspects of the user interface: the interaction point and the viewing angle. Two experimental studies were conducted to validate these choices by investigating their impact on the perceived environment and interface fidelity of the system. The results show that, although the virtual hand increased the user feeling of accuracy when manipulating the virtual needle, it did not increase the overall realism of the environment. One explanation of this finding can be found in the comments of some participants. In fact, since the virtual hand was non-animated, it did not follow the users' finger movements. For instance, some subjects preferred to hold the needle with a pose different from the one represented by the virtual hand. This may have limited the users' feeling of the virtual hand to be their own hand. Regarding the accuracy, the subjects commented that the virtual hand allowed them to have more spatial cues than the two other interaction points. In fact, it gives more information about the depth, and also about the orientation of the needle. The cast shadow was also used as a depth cue. These results suggest that the virtual hand increases the interface fidelity. However, it did not increase the environment fidelity. The use an animated hand could increase the environment fidelity. For that purpose, it will be necessary to track the users' hand and fingers movements and replicate them in the virtual environment. For instance, a noninvasive tracking device (such as a Leap Motion) could be used to avoid disturbing the user while manipulating the haptic device. Moreover, other paradigms, such as allowing users to see their own hand holding the virtual needle [7] should be considered. However, previous studies have shown that environment fidelity is only necessary if it affects positively the interface fidelity [18]. Hence, it is important to determine whether an animated hand will increase the training efficiency of the system.

The second experiment showed that the inclined viewing angle increased the realism, the comfort, and the feeling of accuracy. Almost all the users preferred this viewpoint when compared to the two others. The subjects commented that this angle was the closest to what they have experienced when using the physical setup. Although all subjects commented that they can correctly perform the task with this viewing angle, some of them said that they needed sometimes to change their point of view in order to ensure the needle orientation and/or position was correct. This suggests a lack of interface fidelity related to this 3D navigation task. One option to satisfy this users' need, could be to use a head tracking system. In that case, the display viewing angle will be kept at 45°, while the users will be given the possibility to change freely their viewing angle by controlling the position of the virtual camera using their head movements. Once they have found their best viewing angle, they can then lock the point of view for a more comfortable interaction with the system. The use of an eye tracker should also be considered. Regarding the addition of 3D stereoscopic vision, none of the subjects felt it is necessary for this task.

The two experiments permit then to validate our two user interface components and give some indications on how to improve them for a better interaction with the system.

Design implications

The results of our two studies permit to give some recommendations regarding the design of interactive VR-trainers for a needle insertion task:

- Allowing the user to see his hand when manipulating a surgical tool is important to increase the accuracy when performing a fine motor skill such as a surgical task. In the virtual environment, a virtual avatar of the hand can also increase the depth perception and give additional spatial cues to the user. However, to increase the feeling of presence, it is important to ensure collocation between the virtual hand and the real hand.
- A fixed point of view can be sufficient on a virtual trainer and is suited when performing a fine motor skill such as a surgical task. However, the viewing angle needs to be chosen with caution to ensure that the task can be performed correctly. In fact, the selected angle has to increase the depth perception and permit to accurately manipulate the surgical tool. The users should be given the possibility to choose freely their best viewing angle during the approach phase (when the tool is approaching the target area) while the viewing angle should be locked to increase the comfort during the manipulation phase (when the tool is inside the target area).

LIMITATIONS AND FUTURE WORK

While this work gave us indications about the design of our virtual needle insertion trainer, there are some limitations that should be considered for future developments. First, the subjects recruited for the two evaluation studies were not the end-users of the system. In fact, due to non-availability of expert radiologists, we had to recruit subjects with no clinical experience. While the trainees will also have a limited experience with the needle insertion task, it is important in future studies to involve some experts in the evaluation studies and have their feedback. This is necessary for the face validity of the system. Second, the same subjects participated in both studies. Thus, they may have been influenced in the second experiment by their participation in the first experiment. Therefore, the results of the second experiment need to be considered with caution.

Another limitation of this work is that the evaluation was based only on subjective measurements. In fact, given the simplicity of the experimental task, no differences in performance were expected to be observed. While subjective measurements permit to collect useful users' feedback, it will be interesting in the future to consider also objective measurements such as task completion time, amount of forces and accuracy. These measurements have been already validated by experts in the previous iteration. However, a more complex experimental task should be designed.

One other important aspect to validate is the haptic feedback model. In fact, while the currently implemented model has been validated [2] and is based on interaction with actual organs, it is important to have the users' opinion on the haptic feedback when inserting the needle inside the virtual tissue. One limitation of the previous physical setup was that the silicon samples have different properties than human organs. Thus, the objective will be to show that the simulated tissue has more realistic haptic properties than the silicon which will increase the environment fidelity of the system. For that purpose, two models to simulate needle insertion into a soft tissue will be compared [22,10] and their performance will be evaluated in our simulator.

Once the different user interface components are validated, the last step will be to validate the overall system as a trainer for the needle insertion task.

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