ViTT: Towards a Virtual Reality System that Supports the Learning of Ergonomic Patient Transfers

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Figure 1: The output devices and the two phases supported by ViTT. (A) A Virtual Reality head-mounted display (VR HMD) and vibrotactile gloves are used for visual and haptic output. (B) In Phase I, a nurse can view immersive instructions to understand what is important during different steps of a patient transfer and why. As part of this, the nurse can observe a 3d animation of the transfer. (C) In Phase II, a nurse can train the transfer step by step with a virtual patient. The nurse is supported by in-situ instructions. (material icons in (B), © Google LLC; 3d-avatars in (B) and (C), © Reallusion Inc.; 3d-objects furniture in (B) and (C), © TurboSquid Inc.)

ABSTRACT

While patient transfers are part of nurses' daily work, the manual transfer of patients can also pose a major risk to nurses' health. The Kinaesthetics care conception may help nurses to conduct patient transfers more ergonomically. However, existing support to learn the concept is low. We introduce ViTT, a Virtual Reality system to promote the individual, self-directed learning of ergonomic patient transfers based on the Kinaesthetics care conception. The current implementation of ViTT supports a nurse in two phases: (i) instructions for a patient transfer, and (ii) training of the transfer with a virtual patient (based on a physics engine; implementation limited). In contrast to previous work, our approach provides an immersive experience that may allow for the 'safe' training of different transfer scenarios—e.g., patients with different impairments—and the study of different parameters that may influence nurses' learning experience—e.g., the simulation of stress—in the future.

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CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; **User centered design**; • **Applied computing** → *Life and medical sciences*; *Education*.

KEYWORDS

Virtual Reality, learning, nursing care, kinaesthetics

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1 INTRODUCTION

The manual transfer of patients is an activity that nurses need to conduct globally as part of their daily work. However, the conduct of patient transfers can also pose a major risk to nurses' health (e.g., [16, 21]). Nurses are prevalently affected by work-related musculoskeletal disorders [12], which can lead to functional consequences like missing work, reducing or modifying work activities, or reducing non-work activities [18].

The Kinaesthetics care conception [5]—henceforth abbreviated as *Kinaesthetics*—may help to address the issue. It consists of six concepts, and is supposed to allow for patient transfers so that

nurses' and patients' health development is supported and injuries are avoided (see [7]). Unfortunately, the application of Kinaesthetics in nursing practice is challenging. Various government-supported schools in Germany introduce Kinaesthetics to nursing-care students by providing them with a Kinaesthetics basic course as part of their education. However, aside from the basic course, nursing-care students are hardly provided with any further support for the learning and application of Kinaesthetics [4].

Some past work has explored the use of technology to promote the learning of ergonomic patient transfers. For instance, Huang et al. [9] presented a system that tracks users during training. After the training, a desktop user interface is used to display feedback in the form of a checklist and videos. For the evaluation of their system, the authors had a human act as a patient. Kopetz et al. [11] investigated the use of smart glasses to provide instructions for transferring a patient from a bed into a wheelchair. Similar to Huang et al., a human researcher acted as the patient to evaluate the developed application. Other previous work investigated the use of a robot patient for the training of transfers (e.g., [8]). With a focus on Kinaesthetics, past work mainly explored the use of handheld devices like smartphones and tablets. Two commercial apps [10] were released in the past. The smartphone app 'MH Kinaesthetics' provides images and texts about Kinaesthetics. The tablet app 'Kinaesthetics Care'—which is no longer available in Google's Play Store—aimed to support the training of persons who look after a relative with videos and texts. Aside from the two commercial apps, the tablet app KiTT [2] supports the training of Kinaesthetics-based patient transfers by two nursing-care students in a training room context, together (one acting in the role 'nurse' and one acting as the 'patient'). Finally, Dürr et al. [3] presented NurseCare. The mobile system makes use of a smartphone and a wearable to promote the learning and application of patient transfers based on Kinaesthetics, during work.

Overall, the reviewed work that investigated systems that support the learning of ergonomic patient transfers either supported the learning by two nursing-care students, one acting as the 'nurse' and one as the 'patient' during training, reflected the patient in the form of a robot, provided support during work with real patients, or used a human 'actor' to simulate the patient for the system's evaluation. In contrast to previous work, an immersive Virtual Reality (VR) system may allow for the 'safe,' individual, and self-directed learning of ergonomic patient transfers with virtual instructions and a virtual patient for training. Instead of a real person or a robot patient, a virtual patient can be easily 'exchanged,' which may allow it to provide a simulation of different transfer scenarios—e.g., patients with different impairments—for learning, in the future. This is relevant, as patient transfers may differ for patients with different impairments and movement capabilities [4]. Furthermore, the virtual learning environment can be adjusted. This may prospectively allow it to study the influence of different parameters, like stress, on nurses' learning experience—e.g., by changing how calm or hectic the virtual environment is. Introducing stress may allow for more realistic training situations [4].

We present *ViTT*, the Virtual Reality Transfer Teacher. *ViTT* is a first step towards a Virtual Reality system that supports the learning of ergonomic patient transfers based on Kinaesthetics. *ViTT* makes use of a head-mounted Virtual Reality display (VR HMD) for

output and vibrotactile gloves to provide haptic feedback if interface controls or virtual models—e.g., a virtual patient—are touched (see Fig. 1A). Inspired by part of the procedure of Kinaesthetics basic courses [4], *ViTT* supports learning in two phases: (i) instructions for a patient transfer (see Fig. 1B), and (ii) training of the transfer with a virtual patient (see Fig. 1C).

This work addresses a niche. To our knowledge, there is only few previous work which uses VR to support the learning of complex movements that involve multiple actors, and close physical interactions (e.g., [15, 17]). Patient transfers additionally include verbal communications between patient and nurse. Furthermore, the adoption of immersive VR technology in nursing-care education is in its infancy [6]. There is only few previous work in this area (e.g., [1]).

2 ViTT: THE VIRTUAL REALITY TRANSFER TEACHER

ViTT was implemented with the Unity Engine [19] (primary platform: Windows desktop). Output is provided by a Valve Index VR HMD [20] and ManusVR vibrotactile gloves [13].

The design process of *ViTT* was conducted in German. It was informed by two design walkthroughs with click-through prototypes. Both walkthroughs were conducted with professionals from the target domain, nursing care.

For the current version of *ViTT*, we focused on implementing one exemplary patient transfer: the transfer of a patient with low mobility from a lying position in bed to a sitting position at the bedside. To this end, we reused part of the resources that were created for KiTT [2]. The remainder of the existing resources [2] can allow for a future extension of *ViTT* with transfers for different movement scenarios (e.g., to transfer a patient from a bed into a wheelchair) and virtual patients with different movement capabilities (e.g., a partially mobile or an immobile patient).

In the following, we will introduce the two phases by which *ViTT* supports learning. *ViTT*'s features coincide and differ between the two phases as shown in Fig. 2.

2.1 Phase I: Immersive instructions

In Phase I, a student may observe and control a virtual patient transfer animation (see Fig. 3). The animation is divided into several steps. It can be controlled with a menu attached to the student's secondary hand (see Fig. 3A). The top row of the menu holds three buttons. These allow, from left to right, (i) to jump one step back in the animation, (ii) to play/pause/replay the animation, and (iii) to jump one step forward in the animation. The menu buttons can be pushed with the primary hand. Button presses are visualized by a green highlight of the button (equal as shown in Fig. 4C) and a vibration of the glove at the parts of the hand that touch the button.

The hand menu is not only coupled with the transfer animation but also with an instruction panel. The instruction panel holds textual instructions for the step in the transfer that the animation currently represents, and details about Kinaesthetics that are relevant to the respective step, if applicable (see Fig. 3B, right). The instruction panel is always displayed in the corner of the room that is opposite to the student (see Fig. 3B, left) and rotates towards the student to improve readability.

Feature	Phase I: Immersive Instructions	Phase II: Training of transfer conduct
visualization of patient transfer	3d animation of transfer; see Fig. 3, overview	animated video of transfer; see Fig. 4A
change of bed elevation by student (user)	not supported	touch of control on right side of bed (similar to clinic); see Fig. 4C
transfer of virtual patient by student (user)	not supported	touch of virtual patient by hands; see Fig. 1C and Fig. 4B
hand menu (control of the transfer visualization and instruction panel, audio tracks, and visual highlights)	attached to student's (user's) secondary hand; see Fig. 3, overview and Fig. 3A	attached to left side of bed; see Fig. 4, overview
instruction panel (textual support)	adapts position in the virtual room so that it is displayed in the corner opposite to the student's (user's) position; see Fig. 3B	attached to right side of bed; see Fig. 4, overview
audio tracks (audio support)	track 1 - <i>instructing the patient</i> : mimics how a nurse should instruct the patient track 2 - <i>instructing the student</i> : instructs the student directly (coincides with the information in the instruction panel)	equal to Phase I equal to Phase I
visual highlights	magenta: visualizes where the patient's body parts should be moved to in the current transfer step; see Fig. 3C, top cyan: visualizes the body areas where the virtual instructor touches the patient during the transfer; see Fig. 3C, bottom	equal to Phase I; see Fig. 4B visualizes the body areas where the student (user) touches the virtual patient during the transfer

Figure 2: Feature overview. An overview of the different features that ViTT provides and how those are implemented in Phase I and II.

Figure 3: Phase I: Immersive instructions. (A) A hand menu allows the control of a patient transfer animation (e.g., to jump between the different steps of the animation). (B) An instruction panel provides textual information for the step in the transfer that the animation currently represents (right). The instruction panel adapts its position in the virtual room so that it is displayed in the corner opposite the student's position (left). (C) A student can activate highlights to see the end target position of the patient's body parts for the current step (top), and to see the areas at which the nurse touches the patient (bottom). (material icons, © Google LLC; 3d-avatars, © Reallusion Inc.; 3d-objects furniture, © TurboSquid Inc.)

The bottom row of the hand menu holds two more buttons (see Fig. 3A). Both are toggle buttons. With the left one, a student can

toggle the state of the audio track. Two tracks are available (see Fig. 2). The audio can also be muted. The right button in the bottom

Figure 4: Phase II: Training of transfer conduct. (A) A video view shows the conduct of the current transfer step. (B) Similar to Phase I, a student can activate a highlight to see the end target position of the patient's body parts for the current step. (C) *ViTT* provides buttons to change the elevation of the virtual bed, as this is important to ensure an ergonomic work position. Button presses are reflected by a green highlight, and the parts of the glove with which the student touches the button vibrate to provide haptic feedback. (material icons, © Google LLC; 3d-avatars, © Reallusion Inc.; 3d-objects furniture, © TurboSquid Inc.)

row of the hand menu allows the student to activate a magenta or a cyan highlight (see Fig. 2 and 3C). It is also possible to activate both highlights together and to turn the highlights off.

2.2 Phase II: Training of transfer conduct

In Phase II, a student may actively transfer the virtual patient by moving the patient's body parts with their own hands (see Fig. 1C and Fig. 4B). The vibrotactile gloves provide hand and finger tracking, and per-finger haptic feedback.

ViTT makes use of Unity's physics engine to calculate the impact of forces on the virtual patient. This includes gravity, a student's manipulation of the virtual patient by touch, and resistances through object mass, drag, and colliding objects. The *Puppetmaster* [14] component was integrated into *ViTT*. *Puppetmaster* allows it to 'pin' the virtual patient character that a student can manipulate to an underlying animation of the respective transfer step. In *ViTT*, the pinning forces between the virtual patient character and the underlying animation are used to minimize strong deviations of the virtual patient from the movement path of the animation. They are also used to 'snap' body parts of the virtual patient into the end target position(s) for a transfer step, if a student moves the body part(s) of the virtual patient close to the respective target position(s). Unfortunately, in the current implementation of *ViTT*, the complex interaction of physics forces sometimes leads to errors and consequently an unnatural behavior of the virtual patient character.

In Phase II, a student is supported by an animated video that can be controlled by the hand menu (see Fig. 4A). If a student completes a transfer step by moving the virtual patient's body part(s) to the current step's target position(s), the following step is initiated automatically. However, similar to Phase I, it is also possible to jump between the steps of a patient transfer with the corresponding buttons in the hand menu (see Fig. 3A). Equal to Phase I, the buttons in the bottom row of the hand menu allow it

to toggle between different audio tracks and highlights (see Fig. 2 and 4B). As in Phase I, it is also possible to mute the audio, activate both highlights together, and turn the highlights off. Finally, a student can adjust the virtual bed's elevation, which is important to ensure an ergonomic work position (see Fig. 4C).

3 FUTURE WORK

As part of our future work, we plan to improve the behavior of the virtual patient character during Phase II. We currently consider two different approaches: (i) tying the virtual patient character closer to the behavior of the animation to give less leeway for unexpected behavior, and (ii) coupling the virtual patient with a physical patient model that is tracked. Furthermore, we plan to extend *ViTT* with support for further transfers, and feedback for risky behaviors of a student (e.g., a risky bending of the back). Finally, we plan to evaluate *ViTT* together with potential end-users.

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