KiTT - The Kinaesthetics Transfer Teacher

Design and Evaluation of a Tablet-based System to Promote the Learning of Ergonomic Patient Transfers

Maximilian Dürr
maximilian.duerr@uni.kn
HCI Group, University of Konstanz
Germany

Marcel Borowski
marcel.borowski@cs.au.dk
Department of Computer Science,
Aarhus University
Denmark

Carla Gröschel
carla.groeschel@uni.kn
HCI Group, University of Konstanz
Germany

Ulrike Pfeil
ulrike.pfeil@uni.kn
HCI Group, University of Konstanz
Germany

Jens Müller
jens.mueller@uni.kn
HCI Group, University of Konstanz
Germany

Harald Reiterer
harald.reiterer@uni.kn
HCI Group, University of Konstanz
Germany

Figure 1: The three phases to support the learning of a Kinaesthetics-based patient transfer by two nurses with KiTT: (A) Interactive instructions teach the conduct of the patient transfer step-by-step. (B) During training, visual and auditory key information is provided to support the practice of each step of the patient transfer. An RGB camera records the training of the nurses. Also, risky behaviors of the nurse who conducts the transfer are captured according to seven risk categories (e.g., ‘risky bending of the back’). The Wizard of Oz method was used to simulate the automatic detection of risky behaviors during the evaluation of KiTT. (C) Feedback and reflection are supported by an overview of the detected risky behaviors and the possibility to access details. (material design icons in (A–C), © Google LLC; 3d avatars in (A) and (B), © Reallusion Inc.; 3d hospital furniture in (A) and (B), © TurboSquid Inc.)

ABSTRACT

Nurses frequently transfer patients as part of their daily work. However, manual patient transfers pose a major risk to nurses’ health. Although the Kinaesthetics care conception can help address this issue, existing support to learn the concept is low. We present KiTT, a tablet-based system, to promote the learning of ergonomic patient transfers based on the Kinaesthetics care conception. KiTT supports the training of Kinaesthetics-based patient transfers by two nurses. The nurses are guided by the phases (i) interactive

instructions, (ii) training of transfer conduct, and (iii) feedback and reflection. We evaluated KiTT with 26 nursing-care students in a nursing-care school. Our results indicate that KiTT provides a good subjective support for the learning of Kinaesthetics. Our results also suggest that KiTT can promote the ergonomically correct conduct of patient transfers while providing a good user experience adequate to the nursing-school context, and reveal how KiTT can extend existing practices.

CCS CONCEPTS

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

KEYWORDS

tablet-based system, learning, nursing care, kinaesthetics

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the owner/author(s).

CHI ’21, May 8–13, 2021, Yokohama, Japan

© 2021 Copyright held by the owner/author(s).

ACM ISBN 978-1-4503-8096-6/21/05.

<https://doi.org/10.1145/3411764.3445496>

ACM Reference Format:

Maximilian Dürr, Marcel Borowski, Carla Gröschel, Ulrike Pfeil, Jens Müller, and Harald Reiterer. 2021. KiTT - The Kinaesthetics Transfer Teacher: Design and Evaluation of a Tablet-based System to Promote the Learning of Ergonomic Patient Transfers. In *CHI Conference on Human Factors in Computing Systems (CHI '21)*, May 8–13, 2021, Yokohama, Japan. ACM, New York, NY, USA, 16 pages. <https://doi.org/10.1145/3411764.3445496>

1 INTRODUCTION

The activity to manually transfer patients is critically important as it is a frequent part of nurses' daily work and an activity that is conducted across health systems globally. Unfortunately, nurses are strongly affected by injuries from overexertion [36] and work-related musculoskeletal disorders [44]. Injuries, like problems with the back, neck, and shoulder, can lead to sick leave [14] and long-term medical problems [30]. The manual transfer of patients poses a major risk factor for such symptoms [15, 42].

In Germany, multiple government-supported schools provide nursing-care students with a Kinaesthetics basic course that introduces the Kinaesthetics care conception [3] (henceforth referred to as *Kinaesthetics*). Kinaesthetics is supposed to enable patient transfers in a way so that injuries are avoided, and the health-development of nurses and patients is supported. It consists of six concepts. For instance, the concept 'human function' suggests that fast and too large movement steps—like a swift motion to move a patient upward in bed—should be avoided [23]. These can cause a strong effort to the patient and have an impact on nurses' health. Unfortunately, previous work has shown that the practical application of Kinaesthetics often fails (e.g., [12, 13, 22]). After the Kinaesthetics basic course, nursing-care students are hardly supported in the learning and application of Kinaesthetics [13]. Previous work already showed that mobile technology has the potential to promote ergonomic patient transfers during work [12]. However, there is still the need for further support to foster the learning and, as part of this, training of Kinaesthetics-based patient transfers [12]. We present *KiTT*, the *Kinaesthetics Transfer Teacher*. *KiTT* is a tablet-based system, to promote the learning of ergonomic patient transfers based on Kinaesthetics. Two nurses can use *KiTT* to train Kinaesthetics-based patient transfers by following three consecutive phases. *KiTT* supports the nurses with (i) interactive instructions to understand what is important and why (see Fig. 1A), (ii) key information to support the training of the transfer conduct (see Fig. 1B), and (iii) feedback to aid their reflection (see Fig. 1C).

To our knowledge, *KiTT* is the first tablet-based system that provides instructions and feedback to promote the learning of Kinaesthetics-based patient transfers. Our work contributes an evaluation in a nursing-care school that investigates how nursing-care students experience the support of *KiTT* for learning in a training room context.

2 RELATED WORK

Our work addresses the use of technology to support (i) learning in nursing care, and (ii) movement learning. Thus, we reviewed technical systems that cover either aspect.

2.1 Systems that Support Learning in Nursing Care

Most previous work related to learning systems in nursing care focused on skills that nurses require to care for patients. These include the administration of medication [11], and the placement of a catheter [16] or nasogastric tube [5]. In comparison, only few past work aimed to preserve nurses' health by promoting the learning of ergonomic patient transfers.

Wen et al. [47] proposed a system that tracks a user during the transfer of a patient with a slide sheet and provides visual feedback on a screen. To our knowledge, the system was not evaluated with end-users. Huang et al. [25] introduced a system to train the transfer of a patient from a bed into a wheelchair. Users are tracked during training. Afterward, a desktop computer interface presents users with a checklist and videos for feedback. The authors conducted an experiment in which five participants trained with the system, while five other participants used a textbook and demonstration video. During training, the participants transferred a human who simulated a patient. The authors' results indicate a higher performance improvement for the participants who used the system. Kopetz et al. [29] designed and investigated a smart glasses application that provides instructions for a patient transfer (bed to wheelchair). The authors evaluated the application with 29 nursing-care students. They compared participants' initial performance (pre system use) with participants' performance during the use of the smart glasses. A researcher simulated the patient during the evaluation. The authors' results suggest that smart glasses have the potential to support skills training. Finally, past research also explored the use of a robot patient for the training of patient transfers (e.g., [24]).

In regard to Kinaesthetics, there are two commercial apps that were launched in the past [27]: The smartphone app 'MH Kinaesthetics' is limited to images and texts about Kinaesthetics. The tablet app 'Kinaesthetics Care' was supposed to train persons who look after a relative in need of care. It supported the training of transfers by videos and texts. However, the app is no longer available in the Google Play Store and was, to our knowledge, not evaluated. Furthermore, Dürr et al. [12] conducted an 'in-the-wild' evaluation of NurseCare, a smartphone-based system to promote the learning and application of Kinaesthetics-based patient transfers during work. Based on their results, the authors suggest that additional support to facilitate the acquisition of knowledge in regard to Kinaesthetics-based patient transfers—e.g., in the form of a learning system that can be used in a training room at a nursing-care school—is required. In another work, Dürr et al. [13] present the results of a qualitative study that provides three themes with underlying implications for technology to support the learning of Kinaesthetics-based patient transfers. In their discussion, the authors suggest a concept for a tablet-based learning system. This inspired the design process of our work.

Overall, the reviewed research that investigated systems for the learning of patient transfers in a training room setting either used a simulated human or a robot to reflect the patient during the evaluation. To our knowledge, past research did not provide empirical evidence about how two nursing-care students experience the use

of a tablet-based system that promotes the ergonomic transfer of patients to learn together in a training room context.

2.2 Systems that Support Movement Learning

Much previous research investigated systems to support the learning of movements that are performed by a single human. For instance, past research addressed the learning of tai chi movements in virtual reality [6], violin playing with a vibrotactile jacket [46], and arbitrary single-person movements with an augmented reality mirror [1].

Aside from this, some recent work used virtual reality displays to support the learning of complex movements that involve two actors. Senecal et al. [40] introduced a system for the learning of dance movements with a virtual partner. Related, Takala et al. [43] presented a martial arts training system that supports the interaction with virtual opponents.

Considering handheld devices, there exist several commercial movement learning and training apps. Many of these focus on single-user fitness exercises (e.g., [19]). Besides this, there is also a commercial augmented reality app [10] that supports the couple practice of salsa. Users can see footsteps, augmented on the floor, that they can follow.

Overall, there are few systems that use tablets to support the learning of complex movements that involve multiple human actors. To our knowledge, previous work did not investigate the use of tablets to support the learning of complex patient transfer movements that involve two actors, close physical contacts, and verbal communications.

3 KiTT: TEACHING KINAESTHETICS-BASED PATIENT TRANSFERS WITH TABLETS

In the following, we describe the design and implementation of *KiTT*, the *Kinaesthetics Transfer Teacher*. *KiTT* is a tablet-based system that aims to promote the learning of ergonomic patient transfers, based on Kinaesthetics. The design process was conducted in German. All parts of the user interface shown in this section are translated into English.

3.1 Design Goals

We based our design process on the results of a previously conducted qualitative study [13]. The authors provide three themes (theme 1–3) with underlying implications to support the learning of Kinaesthetics-based patient transfers by technology. We established three goals—each related to one theme—that guided the design process of *KiTT* (DG1–DG3).

DG1 *Support self-directed learning by instruction, training, and feedback.* The results of *theme 1, learning and application* [13] stress the need to support the self-directed learning of Kinaesthetics-based patient transfers. At present, nursing-care students lack an adequate support to continue learning after they participated in a Kinaesthetics basic course. The availability of professional teachers is strongly limited. During basic courses, teachers typically follow a procedure with three main components: (i) *instruction*, (ii) *training*—original wording: “*practice*”—, and (iii) *feedback*. When designing *KiTT*, we aimed to support the self-directed learning by two nurses after

participation in a Kinaesthetics basic course. We structured the learning by the aforementioned three components to provide users with a familiar basis.

DG2 *Support practical experiences from the ‘nurse’ and ‘patient’ perspective and the reflection on these experiences.* The results of *theme 2, experience* [13] show that teachers see practical experiences as an important part of Kinaesthetics courses. Students usually train patient transfers while enacting the roles ‘patient’ and ‘nurse.’ Taking on the ‘patient’ role can increase students’ understanding of human movement possibilities and patients’ feelings. Teachers also encourage students to instruct the patient to participate in the transfer, as effective movement and action dialogues can help to reduce the load on the body of the nurse who interacts with the patient [7]. Furthermore, teachers encourage students to think about their training experiences. This process is frequently guided by risky behaviors that the teacher identified. We designed *KiTT* to support the learning in the roles ‘nurse’ and ‘patient.’ To increase the understanding of correct nurse-patient interactions, *KiTT* exemplifies the patient’s active involvement in a transfer. Finally, *KiTT* was designed to aid the reflection on training experiences in association with risky behaviors.

DG3 *Support the link between theory, body, and movement for diverse patient transfer situations.* The results of *theme 3, body and movement* [13] highlight that different patients might require different ways to transfer them. For example, nurses sometimes need to transfer patients with a higher or a lower movement capability—e.g., a partly mobile patient in rehabilitation vs. a mostly immobile patient who requires intensive care. Depending on the situation, different parts of Kinaesthetics might be more or less relevant. Teachers typically illustrate how Kinaesthetics as a theory can help to understand the human body and its movement capabilities, and how this can ease patient transfers during different situations. When designing *KiTT*, we considered the need to support the learning of different patient transfer situations. We also aimed to provide a close link between Kinaesthetics and its application, as this might aid students’ understanding of how Kinaesthetics can support them to handle different patient transfer situations ergonomically.

3.2 Design Process

As part of our design process, we created content together with nursing-care teachers ($N = 4$) and conducted a formative evaluation of *KiTT_{pt}*, a prototype of *KiTT* with nursing-care students ($N = 18$).

Content Creation. To facilitate the instruction of learners (see **DG1**), we created *animations* for eight Kinaesthetics-based patient transfers. We used 3d motion capturing to record transfers for three movement scenarios that nurses often need to carry out: (i) transfer a patient upward in bed, (ii) transfer a lying patient to sit at the bedside, (iii) transfer a patient from the bedside into a wheelchair. Related to **DG3**, for each scenario, we captured transfers that are suitable for patients with different movement capabilities. The captures were created with a professional Kinaesthetics teacher who had 16 years of experience with Kinaesthetics. The teacher demonstrated the transfers with a student who acted as the patient (see Fig. 2A). We captured the transfers with two body-worn Perception

Figure 2: Design Process. (A) Eight transfers were captured with a teacher. (B) Based on the captures, we created eight animations. These were reworked, based on experts' feedback. (C) *KiTT_{pt}*—a prototype of *KiTT*—was formatively evaluated with 18 nurses. (material design icons in (c), © Google LLC; 3d avatars in (B) and (C), © Reallusion Inc.; 3d hospital furniture in (B) and (C), © TurboSquid Inc.)

Neuron suits (version 'V1') [35] and post-processed the best captures with iClone (version '7') [26]. This resulted in one animation for each of the eight transfers. We reworked the animations based on the feedback of four nursing-care teachers (two female). The teachers were between 31 and 61 years old ($M = 49.00$, $SD = 10.32$) and had, on average, 14.75 years of experience with Kinaesthetics ($SD = 2.28$). Fig. 2B shows an example of the final result.

Each animation consists of different steps. Besides feedback for animations, we also asked the nursing-care teachers how Kinaesthetics can help to carry out the different parts of each patient transfer, and what other information might be relevant to a learner and why. Based on the teachers' input, we created *instruction texts* for the different steps of each transfer. The texts were evaluated by the teacher who supported the motion capturing, and afterward corrected. The teacher also helped us to render *videos* from the animations. The videos change the visual perspective on the transfer, dependent on the information that is—according to the Kinaesthetics teacher—most relevant for the respective step. Finally, for the motion capturing, we instructed the teacher to communicate with the student, similar to a real patient. The recorded *audio track* exemplifies how a nurse can instruct a patient to participate in a patient transfer (see **DG2**).

KiTT_{pt}, a prototype of *KiTT*. We used the design goals (**DG1**–**DG3**) and qualitative input from the teachers who supported the content creation to design and implement *KiTT_{pt}*, a prototype of *KiTT* (see Fig. 2C). We aimed to support mobile use and the use of the app in a training room at a nursing-care school. Two nurses can use *KiTT_{pt}* on two iPads to learn together. The prototype was formatively evaluated with 18 nursing-care students (15 female), who participated in nine dyads. They were between 19 and 30 years old ($M = 23.11$, $SD = 3.5$). Each dyad received a pair of iPads with chargers (screen diagonal 9.7"). For each dyad, we initially introduced *KiTT_{pt}*. As part of this introduction, we explained *KiTT_{pt}*. Subsequently, we

asked the dyad to learn a randomly assigned transfer with *KiTT_{pt}*. After the initial use, the participants filled the User Experience Questionnaire [31], and we captured their first impressions with a semi-structured interview. Afterward, the participants took the iPads with them for seven days. We asked them to explore all of the patient transfers offered by *KiTT_{pt}* and to use the app at least three times to learn together. After the 'in-the-wild' use, we conducted a second semi-structured interview to ask about the participants' experiences with *KiTT_{pt}*. The participants received 50 Euro as compensation.

The results of the User Experience Questionnaire indicate that the app's attractiveness ($M = 1.83$) and the hedonic quality aspects ($M = 2.00$) were rated higher than the pragmatic quality aspects ($M = 1.39$). The formative evaluation revealed multiple usability problems that might be related to the lower rating of the pragmatic quality aspects. For instance, the evaluation showed that *KiTT_{pt}*'s guidance along the learning process was not strict enough, and revealed limitations in the support of the roles 'patient' and 'nurse.' Also, *KiTT_{pt}* did not include a feedback for risky behaviors that occurred during the patient transfer, yet. The final implementation of *KiTT* provides a stricter guidance along the learning process, a clear assignment and a deeper embedding of the roles 'patient' and 'nurse,' and feedback for risky behaviors. Besides this, we also addressed multiple other problems that the formative evaluation helped to uncover.

When addressing the problems that we identified in the formative evaluation, we focused on fixing the most relevant problems with the available resources until the date for the evaluation of the final implementation (schedule dictated by the research project that founded our work). Although the formative evaluation showed that there were still some limitations in the animations' quality, we did not improve the animations' quality further due to resource limitations.

3.3 KiTT: The Final Implementation

KiTT is an iPad app that was created with Unity 3D [45]. *KiTT* was developed in the context of a larger research project. For the final implementation, we implemented an interface to connect *KiTT* to a tracking system that can be installed in a nursing-care school's training room. Our project partners developed a software component that uses the tracking system to detect risky behaviors when two nurses train a transfer. This software component runs on a separate computer. Our final implementation uses a computer with a Photon server instance [18], a router, and the Photon PUN Unity asset [17] to send data between the iPads. The computer is also used to forward data about risky behaviors and the stream of an RGB camera, that records the nurses during training, to both iPads. Unfortunately, the software component for the detection of risky behaviors was not completed in time with *KiTT*. To compensate for this, we used the Wizard of Oz method to simulate the automatic detection of risky behaviors. Our final implementation addresses the design goals (DG1–DG3), as described in the following.

DG1 *Support the self-directed learning by instruction, training, and feedback.* *KiTT* provides a Menu to select a patient transfer for learning. Afterward, the nurses are guided by the phases Phase I: Interactive instructions, Phase II: Training of transfer conduct, and Phase III: Feedback and reflection. For an overview, see Fig. 3.

Menu. The app *KiTT* makes use of a two-level menu. In the top-level menu (see Fig. 3, *Menu*), the nurses can select a patient transfer scenario for learning (e.g., to sit up a patient to the bedside). Afterward, the second-level menu provides an overview on different transfers for the selected scenario. The offered transfers differ in their suitability for patients with different movement capabilities (also see implementation description DG3). After the nurses select a patient transfer, they are asked to distribute the roles 'nurse' and 'patient' (also see implementation description DG2). Only one nurse can control the menu. Each nurse receives their own user color—yellow or cyan—which is shown in the top right corner (e.g., yellow humanoid icon in Fig. 3). Both nurses see the corners of a rectangle around the menu. The rectangle corners are colored in the user color of the nurse who has control over the menu (e.g., yellow in Fig. 3, *Menu*).

Phase I: Interactive instructions. In phase I, *KiTT* provides a view on a 3d animation of the patient transfer that the nurses learn together (see Fig. 3, *Phase I*, right). Based on ARKit [2], the 3d animation can be placed on a real-world surface and viewed in augmented reality. Both nurses can view the same 3d animation, scale and rotate it by touch gestures, and walk around it to watch it from different perspectives. The nurses can discuss the patient transfer in relation to the 3d animation that they both see at the same physical location in the real world. Although our approach only provides a loose connection between the physical context and the virtual content, the place-independent implementation can allow for a future mobile use at different real-world locations [28]. *KiTT* offers a brief augmented reality tutorial at the beginning of phase I. We added the tutorial after the formative evaluation, as we aimed to make the final version of *KiTT* self-explaining. The tutorial asks a nurse to walk to blue spheres to familiarize themselves with the navigation by physical locomotion. The tutorial can be skipped. The 3d animation can be controlled by buttons and a timeline (see Fig. 3, *Phase I*, bottom). The timeline is split according to the steps

of the patient transfer. Both nurses can watch the 3d animation independent from one another. Two triangles—in the respective user color—indicate which part of the 3d animation each of the nurses currently watches. If the nurses want to discuss a part of the 3d animation, one nurse can drag the triangle with his/her user color to the position of the co-learner's triangle. In contrast to the playback of the 3d animation, the scaling and rotation of the 3d animation by touch gestures is synchronized between the iPads. This decision was made to give the nurses a better foundation for discussions. There are four buttons on the left of the timeline. From left to right, these support: (i) the playback/pause of the animation, to jump to (ii) the previous or (iii) the next step of the transfer, and (iv) to switch between a looping playback of the current step and a playback of the whole patient transfer. The two buttons right of the timeline support: (i) the enabling/disabling of an audio track that exemplifies the correct instruction of the patient, and (ii) the enabling/disabling of a subtitle for the audio track. Finally, there is a side panel with two tabs on the left of the screen. The left tab provides an overview on key aspects that should be considered for the conduct of the patient transfer (e.g., to adjust the bed elevation properly). The right tab provides information for the patient transfer step that a nurse currently views in the 3d animation. This includes a description of how the respective step should be conducted, as well as explanations of relevant parts of Kinaesthetics where appropriate (e.g., the concept 'human movement', in Fig. 3, *Phase I*).

Phase II: Training of transfer conduct. After both nurses explored the instructions for a patient transfer, *KiTT* provides a step-by-step support during the training of the transfer conduct (see Fig. 3, *Phase II*). In phase II, both iPads are fully synchronized. The nurse who conducts the patient transfer can use one or both iPads to receive key information about the conduct of each transfer step (e.g., by putting an iPad on a nightstand like shown in Fig. 1B). *KiTT* provides a short audio instruction for each step of the transfer. Additionally, each step is visualized in the form of a short video sequence. The video changes the visual perspective dependent on the information that is most relevant for each part of the transfer (see section 3.2). The nurse who conducts the patient transfer can tap the left or right portion of the screen to access the previous or next step in the transfer. A tap in the screen's middle pauses or resumes the video playback. The three functionalities can also be accessed by the small buttons on the left of the timeline. The button on the right of the timeline allows the muting and unmuting of the audio instructions.

Phase III: Feedback and reflection. After the training, *KiTT* provides feedback and supports the nurses in their reflection. An RGB camera is used to record the training of the nurses in *Phase II* (see Fig. 1B). In *Phase III*, the nurses can rewatch their training in form of a video that is shown on the right side of the user interface (see Fig. 3, *Phase III*). *KiTT* can provide feedback for seven risk categories: (i) bed elevation not adjusted for ergonomic work, (ii) arms bent when moving the patient, (iii) own body alignment contrary to movement direction of patient, (iv) small support base, (v) legs stretched out/no squat, (vi) risky bending of the back, (vii) grabbing of a 'space between bodily masses' (e.g., the waist [23]). The risk categories were defined based on input of nursing-care teachers ($N = 5$). The panel on the left side provides two tabs. If the left tab is active, the panel shows an overview on how frequently a risky

Figure 3: The final implementation of *KiTT*. *KiTT* provides a menu to select a patient transfer for learning. Afterwards the learning is guided by three phases: In phase I, nurses are provided with interactive instructions to help them understand what is important about the selected transfer and why. In phase II, the nurses receive key information to help them train the transfer together. In phase III, the nurses are provided with feedback and encouraged to think about what they did and how they can improve next time. After phase III, the nurses can either repeat the phases I–III to deepen their understanding of the learned transfer, or select a different transfer for learning. (material design icons, © Google LLC; 3d avatars, © Reallusion Inc.; 3d hospital furniture, © TurboSquid Inc.)

behavior was detected for each of the risk categories. The timeline below the video supplements this information by highlighting the time frames for which a risky behavior was detected during the training of the nurses. A nurse can click the button on the left of the timeline to play/pause the video. Similar to *Phase I*, a triangle

in the respective user's color indicates which part of the recording each of the nurses currently watches. Inspired by the Information-Seeking Mantra [41], the nurses can access details about the time frames for which a risky behavior was detected on-demand. The right tab in the side panel is linked to the timeline. The shown

details are related to the position of the triangle in a nurse's own user color on the timeline. The detail-view provides the nurses with (i) a reflective question, (ii) an explanation of why the behavior is risky, and (iii) information about how the risky behavior can be avoided in the future (see Fig. 3, *Phase III*). The nurses can use the feedback to reflect on their experiences individually and discuss them with their co-learner (see Fig. 1C).

DG2 *Support practical experiences from the 'nurse' and 'patient' perspective and the reflection on these experiences.* KiTT encourages the nurses to alternate between the roles 'patient' and 'nurse.' After selecting a patient transfer, the nurses can make the role assignment. During *Phase I–III*, the respective role of each nurse is shown in the upper right corner (see Fig. 3, *Phase I–III*). The texts in KiTT differ for the roles 'patient' and 'nurse.' For example, if the risky behavior *arms bent when moving the patient* was detected, KiTT provides the 'patient' with the reflective question "Did the movement feel natural to you as a patient?," and the 'nurse' with the question "Did you find the movement strenuous?"

DG3 *Support the link between theory, body, and movement for diverse patient transfer situations.* KiTT supports the learning of patient transfers for patients with different movement capabilities. These range from patients who are physically 'very mobile'—e.g., patients who have a mental disease—to patients who are 'very immobile'—e.g., patients who are in a coma. Throughout all three phases of the learning process, KiTT provides a close link between Kinaesthetics and the ergonomic movement of the patient's body. In *Phase I*, the Kinaesthetics theory is entangled with a demonstration of the transfer conduct. In *Phase II*, a concise audio track provides theoretical key information while a video visualizes the correct application. In *Phase III*, the feedback provides theoretical input about how risky behaviors can be avoided.

4 EVALUATION: A USER STUDY IN A SKILLS-LAB CONTEXT AT A NURSING-CARE SCHOOL

Skills-labs are training rooms in nursing-care schools. Kinaesthetics basic courses usually take place in a skills-lab, if such a room is available. Skills-labs typically contain hospital beds and other medical equipment. The final implementation of KiTT was designed to support the learning of Kinaesthetics-based patient transfers by two nurses in a skills-lab. To our knowledge, previous research did not provide empirical evidence for the use of a tablet-based system that promotes the learning of ergonomic patient transfers in a skills-lab at a nursing-care school. To determine how well a system like KiTT addresses nurses' needs, we conducted a qualitative mixed-methods user study with 26 nursing-care students in a skills-lab context at a nursing-care school. We addressed three research questions (**RQ1**–**RQ3**).

RQ1 *Does a system like KiTT provide a high user experience, adequate to support nurses' learning in a skills-lab context?*

RQ2 *To what extent can a system like KiTT promote the learning of Kinaesthetics for the ergonomic transfer of patients?*

RQ3 *How can a system like KiTT integrate into and extend conventional practices to support the learning of Kinaesthetics?*

4.1 Participants

26 nursing-care students (21 female) participated in the user study. They formed 13 dyads. The nursing-care school that supported the study and the participants were different from the ones who aided our design process. During the study, all participants went to class at the nursing-care school that supported the study. The participants were between 19 and 29 years old ($M = 21.54$, $SD = 2.04$). All participants were in the fifth semester of their education. They had all participated in a Kinaesthetics basic course. One participant only participated in the first two of three course days.

4.2 Apparatus

The user study was conducted in a room in a nursing-care school. The room was not the school's skills-lab (otherwise occupied). We equipped the room with a hospital bed and a wheelchair to reproduce the setting of a skills-lab. We used two Apple iPad 2018 (screen diagonal 9.7") for the study. Each iPad was provided with a cover that can be converted to a stand. We used a large printed marker to denote an 'instruction area' on the floor, next to the hospital bed that the nurses used for training. The 3d animation was visualized above the 'instruction area.' We used a router and a computer for the communication between the iPads, and to forward data about detected risky behaviors and the stream of a Logitech C920 webcam [33], that recorded the nurses during their training, to both iPads. The computer had a 6th generation Intel i7 CPU, 32 GB RAM, and a GeForce GTX 745 installed. As stated in section 3.3, our project partners worked on a software component to detect risky behaviors during the training of patient transfers. As the component was not completed in time for the evaluation of KiTT, we simulated the detection of risky behaviors by use of the Wizard of Oz method. We implemented a user interface that allows it to press a keyboard key to simulate the detection of a risky behavior related to any of the seven risk categories. A research assistant monitored the training of the participants. If the research assistant detected a risky behavior, she pressed the corresponding keyboard key for the duration in which the risky behavior was present. Although the research assistant was no expert in Kinaesthetics, she had worked on a larger research project related to the topic for two years and was familiar with Kinaesthetics and the risk categories.

4.3 Procedure

The study duration was 120 min per dyad. It consisted of an introduction, a transfer task (pre system use), a training task, a scenario-based use of KiTT, a second transfer task (post system use), and a closing interview.

Introduction. Initially, the participants were informed about all data that were collected during the study. They all consented to the collection and the later use of the data by signing an informed consent. Afterward, the participants were asked to fill a demographic questionnaire.

Transfer task (pre system use). After the introduction, each dyad member was asked to transfer a simulated patient according to a pre-defined scenario (see Fig. 4). After the transfer, each participant filled a 'Self Evaluation Questionnaire.' Before one dyad member conducted the transfer and filled the questionnaire, the other one

Initial situation: Mrs. Maier slid down in her bed	Task: Transfer Mrs. Maier from her bed into a wheel-chair (so that she can be brought to the wash basin afterwards)
Target situation: Mrs. Maier wants to get to a wash basin	Profile of Mrs. Maier: • 68 year old • COPD (chronic obstructive pulmonary disease) • slid down far and lies with strongly bent legs in bed • heavy smoker • exertional dyspnea (difficulty breathing) • is immobile; i.e., can neither stand up, nor walk alone

Figure 4: Scenario for the patient transfer task (pre and post system use) and the scenario-based use of KiTT.

was asked to leave the room. Afterward, the dyad members switched places. The patient was simulated by a research assistant (female).

Training task. Each dyad completed a training task to familiarize themselves with KiTT. We asked each dyad to learn a specified transfer with KiTT: the transfer of a mobile patient from the bedside into a wheelchair. We chose this transfer as it is not suitable for the scenario that we used for the pre/post transfer task and the scenario-based use (see Fig. 4).

Scenario-based use. After the training task, we asked each dyad to use KiTT to learn and practice for the transfer of Mrs. Maier according to the scenario that they initially received (see Fig. 4). The scenario-based use stretched at least 15 min per dyad. If 15 min were over and a dyad was currently involved in the learning of a transfer, we waited until they finished the learning process. Afterward, we ended the scenario-based use and asked each participant to fill the User Experience Questionnaire [31] and a custom ‘System Evaluation Questionnaire’ in the given order.

Transfer task (post system use). After the scenario-based use, each dyad member was asked to apply what he or she had learned with KiTT to transfer the simulated patient according to the pre-defined scenario (see Fig. 4) once more. After the transfer, the participants filled a second ‘Self Evaluation Questionnaire.’ Again, one dyad member was asked to leave the room while the other conducted the transfer and filled the questionnaire. Afterward, they switched places.

Closing. At the end, we conducted a semi-structured interview. After their participation, the participants were informed that they should not take the app’s feedback serious as the app was still under evaluation. After all of the participants took part, we sent an additional e-mail to inform the participants about the Wizard of Oz. The participants received no financial compensation.

4.4 Measurements

User Experience Questionnaire. After the scenario-based use of KiTT, we captured participants’ experiences with the User Experience Questionnaire [31]. The questionnaire is based on a 7-point scale. Similar to the UEQ Data Analysis Tool [39], in section 4.5, we report the ratings of the User Experience Questionnaire in the range from -3 (most negative value) to 3 (most positive value).

‘System Evaluation Questionnaire.’ Additionally to the User Experience Questionnaire, we asked participants to fill a custom ‘System Evaluation Questionnaire’ with 5-point semantic differential scales. Besides users’ experience (see RQ1), the ‘System Evaluation Questionnaire’ includes questions about the extent to which KiTT helped to increase participants’ knowledge of Kinaesthetics, and the extent to which KiTT could help to improve the practical application of

Kinaesthetics (see RQ2). Related to RQ3, the questionnaire also inquired about the extent to which the participants would consider it as desirable to integrate KiTT into conventional teaching methods. In section 4.5, we report the ratings of the ‘System Evaluation Questionnaire’ in the range from 1 (most negative value) to 5 (most positive value).

‘Self Evaluation Questionnaire.’ After the pre and post system use transfer task, participants filled a custom 5-point ‘Self Evaluation Questionnaire’ with semantic differential scales. Related to RQ2, the questionnaire includes questions about how ergonomically correct, and how conform with Kinaesthetics the participants estimate the movement sequence that they performed. In section 4.5, we report the ratings of the ‘Self Evaluation Questionnaire’ in the range from 1 (most negative value) to 5 (most positive value).

Semi-structured interview. The questionnaires were complemented by a semi-structured interview. The interview allowed us to get a deeper insight into users’ experiences with KiTT, to what extent KiTT helped to promote the learning of Kinaesthetics, and how KiTT might extend conventional practices. The interview was conducted with both members of a dyad at the same time and audio recorded. We conducted a thematic analysis with Taguette [37]. The thematic analysis followed the steps described by Virginia and Clarke [4]: First, we transcribed all interviews and familiarized ourselves with the data. Second, we assigned initial codes to interesting parts of the data. Third, we sorted and compared the codes to generate themes. Fourth, we iteratively refined the themes. As part of this, we collapsed themes, broke themes down, and omitted themes that contained not enough data to support them. Fifth and sixth, we named and documented the themes, including a quantification of similar statements from the participants.

Video recording of transfer tasks. We used two video cameras to record the transfer tasks that the participants completed pre and post system use, and the system use itself. One camera was mounted above the bed, and one recorded participants from the side. We coded the videos of the scenario-based use with BORIS [21] to extract participants’ usage times, occurrences of technical problems, and to count the training in the roles ‘nurse’ and ‘patient’ by each participant.

Video evaluation by a professional Kinaesthetics teacher. Additionally to the participants’ subjective ratings, we asked a professional Kinaesthetics teacher for his opinion (male, 16 years experience with Kinaesthetics). We post-processed the video recordings of the pre and post-transfer task. For each transfer, we merged the videos that provide a view from the side and from the top. We also improved the audio quality. We created a Limesurvey [32] that allowed a rating of the videos. The teacher filled the survey at home. For

each video, the teacher answered semantic differential scales to rate how ergonomically correct, and how conform with Kinaesthetics he estimated the movement sequence shown in the video. Additionally, for each video, the teacher provided bullet point answers about what he deemed *not* ergonomically correct, and *not* conform with Kinaesthetics. To avoid a bias, we did not inform the teacher about the context in which the videos were created before he completed the rating of all videos. The teacher was initially informed that the videos show patient transfers by nursing-care students, but not which videos we created pre and post system use. Before the teacher had rated all videos, he was neither informed that the persons in the videos had used *KiTT* nor that the difference between pre and post system use videos exists. The videos were balanced so that pre and post system use was mixed and so that there were at least 14 videos with other participants between two videos of the same participant. The teacher's bullet point answers were analyzed by a thematic analysis, similar to the analysis of the interview data.

Data collection by our research partners. Besides us, two of our research partners collected data during the evaluation. One asked the participants to fill a custom questionnaire with a socio-pedagogical focus before the use of *KiTT*. The second collected data about the participants' patient transfers with two tracking cameras.

4.5 Findings & Discussion

In the following, we report and discuss our findings in relation to our three research questions. Our evaluation addressed users' experience with *KiTT* (RQ1), to what extent a system like *KiTT* can help to promote the learning and application of Kinaesthetics (RQ2), and how a system like *KiTT* may integrate into and extend conventional practices (RQ3). All reported results and quotes were translated from German to English. The statements of different participants are distinguished by different identifiers. An identifier consists of the letter *D* followed by the *dyad's number* and—if required—an *a* and/or *b* to indicate the *dyad member(s)* (e.g., D1a = dyad 1, member a). We used t-tests to analyze the subjective ratings of the pre/post system use transfer tasks. The significance level α is at .05. Furthermore, we encountered some technical issues during the study and excluded some data as part of our analysis.

The user study was affected by two technical issues. During the scenario-based use, *KiTT* was restarted once for four dyads to resolve a drift-issue with the ARKit tracking (D3, D4, D9, D12). Aside from the tracking issue, the stream from the RGB camera was not always shown correctly during phase III (feedback and reflection). For 13 participants, it happened once that they saw a white rectangle instead of the video of their training conduct (D1a, D2a+b, D3a+b, D5a, D6b, D7a+b, D10b, D12a+b, D13b). D9b was affected twice, and D9a thrice. Still, 18 participants completed phase III for at least one patient transfer that they trained in the role 'nurse' without having the white-rectangle issue on their iPad. Of the remaining eight participants, five never assumed the role 'nurse' during training (D1b, D4a, D9a, D10a, D12b). The participant D6b assumed the role 'nurse' only once and was affected by the white-rectangle issue. The members of D7 were affected by the white-rectangle issue initially and did not use *KiTT* to discuss their training afterward.

We excluded some data as part of the analysis related to (RQ1): When we computed how long the dyads used *KiTT* to learn according to the scenario, we excluded the time that it took to restart *KiTT* when the drift-issue with the ARKit tracking occurred. When analyzing the ratings for the User Experience Questionnaire, we excluded the ratings of D2a, as the participant's data showed up as suspicious in the *inconsistencies* sheet of the UEQ Data Analysis Tool [39]. We also excluded some data as part of the analysis related to (RQ2): The participant D10a did not complete the pre and post system use transfer tasks successfully. We, therefore, excluded the participant's data for the analysis of the 'Self Evaluation Questionnaire' and the evaluation of the transfer tasks by the professional Kinaesthetics teacher. Finally, we analyzed the ratings of the transfer tasks by the professional Kinaesthetics teacher twofold: First, for all participants except D10a. Second, we also analyzed the ratings for the 18 participants who completed phase III (feedback and reflection) for at least one patient transfer that they trained in the role 'nurse' without having the white-rectangle issue on their iPad. For the second measure, we excluded the eight participants mentioned above: D1b, D4a, D9a, D10a, D12b (never assumed the role 'nurse' during training), and D6b and D7a+b (were affected by the white rectangle issue).

(RQ1) *User experience.* The dyads used *KiTT* for 20.59 min on average to learn according to the scenario ($SD = 3.32$ min). Despite the technical limitations, the participants were mostly positive about their experience with *KiTT*. For example, one participant stated:

"But, I liked [KiTT], because it provided a good overview, it was clear what to do, what kind of limitations the patient has, and I liked the explanations [...]." (D4a)

The ratings of the User Experience Questionnaire by 25 of the participants confirm this. *KiTT's* attractiveness ($M = 2.18$, $SD = 0.60$), efficiency ($M = 1.82$, $SD = 0.56$), dependability ($M = 1.72$, $SD = 0.64$), stimulation ($M = 2.30$, $SD = 0.58$), and novelty ($M = 2.18$, $SD = 0.70$) were rated as *excellent* [38]. The app's perspicuity ($M = 1.25$, $SD = 0.83$) was rated *above average* [38]. Also confirming participants' positive opinion, the mean scores of the 'System Evaluation Questionnaire' indicate that participants did experience the learning with *KiTT* as helpful, that they would recommend *KiTT* to a colleague, and that *KiTT* supported them well in learning together with their co-learner (see Fig. 5).

The data of the closing interview also suggests a mostly positive user experience. The participants named more positive than negative aspects related to the three design goals that we followed for the creation of *KiTT* (see Fig. 6).

Related to (DG1), the participants appreciated the familiar structuring of *KiTT* in the three phases (i) interactive instructions, (ii) training of transfer conduct, and (iii) feedback and reflection. Participants' mean scores of the 'System Evaluation Questionnaire' confirm that the participants found *KiTT's* structure helpful to learn and practice (see Fig. 5).

"Well, I, I think that is just also this usual procedure that we have here [at school]. So we know it like this. First explaining, then training, then feedback, and then maybe another repetition." (D13b)

Figure 5: Mean scores of the 5-point semantic differentials in the custom ‘System Evaluation Questionnaire.’

design goal	positive aspects	n	negative aspects	n
DG1 Support self-directed learning by instruction, training, and feedback	<ul style="list-style-type: none"> + animations can be viewed from different perspectives + instructions can be repeated at will + helpful that the transfers are divided in steps + review of own performance helpful for feedback + structure in three phases helpful/good + highlighting of risky behaviors helpful/good + animations can be explored by walking + structure in three phases familiar from school + supports the direct training of learned content + direct application of feedback possible + augmented reality makes instructions more realistic + provides visual key information during training 	20 (4) 11 (5) 11 (5) 9 (2) 9 (3) 8 (1) 8 (2) 4 (1) 4 (2) 3 (1) 2 (0) 2 (2)	<ul style="list-style-type: none"> - animations are sometimes not clear enough - augmented reality tutorial was confusing - audio is off during training by default - meaning of bars in feedback timeline not clear enough - augmented reality weird/confusing - augmented reality is not so important/video would suffice - state indicator (triangle) cannot be slid along the timeline during video playback in feedback (only if video paused) - no in-situ feedback - augmented reality tracking was unstable 	10 (0) 10 (3) 7 (2) 4 (1) 2 (0) 2 (0) 2 (1) 1 (0) 1 (0)
DG2 Support practical experiences from the ‘nurse’ and ‘patient’ perspective and the reflection on these experiences.	<ul style="list-style-type: none"> + different roles provide different insights/experiences + supports reflection/discussion + role distribution familiar from school 	7 (1) 6 (1) 2 (0)	<ul style="list-style-type: none"> - not supported to switch roles during phase II (training of transfer conduct) 	4 (1)
DG3 Support the link between, theory, body, and movement for diverse patient transfer situations.	<ul style="list-style-type: none"> + theory explanations aid understanding + most relevant patient transfer scenarios included + <i>KiTT</i> reminds about important theoretical key aspects + theory familiar from school 	7 (0) 2 (0) 2 (1) 2 (1)	<ul style="list-style-type: none"> - more time required to fully read theory related texts - repetition of theory from school superfluous - did not learn the transfers in <i>KiTT</i> at school (D10a, who did not complete the pre/post system use transfer tasks) 	5 (1) 1 (0) 1 (0)

Figure 6: Positive and negative aspects of *KiTT*, related to the three goals that guided the system’s design. The number without brackets behind each aspect in the column *n* indicates the aggregated number of the 26 participants who stated the aspect direct (by themselves) or indirect (by confirming their co-learner). The number in brackets reflects the number of participants who stated the aspect indirect.

The participants particularly liked it, that *KiTT* allows it to view the patient transfer animations from different visual perspectives, to repeat the instructions at will, and to review their performance after the training, including the highlighting of detected risky behaviors. They also appreciated that the instructions are divided into clear steps. However, the participants especially mentioned the following three limitations: They found the augmented reality tutorial initially confusing, as the tutorial’s task—to walk to blue spheres to familiarize with the navigation by physical locomotion—had nothing to do with the learning of patient transfers. As most participants

quickly familiarized themselves with the use of augmented reality despite the confusion caused by the tutorial, the tutorial might be removed in the future. Also, the animations were sometimes not clear enough. The participants could sometimes not clearly identify where they should hold or move a part of the patient’s body or give an impulse to initiate a movement step. This might also be related to the fact that the animation data are, despite our efforts during the post-processing, not entirely free of perceptible drifts. Finally, the key audio instructions during training were disabled by default. This caused some participants to miss them.

Related to **DG2**, six participants mentioned that *KiTT* stimulated them to reflect and discuss. They also appreciated it that they could train in the roles ‘nurse’ and ‘patient,’ as this provides different views on the transfer conduct.

Because one can, should also feel like the patient once [...] Because [to understand the patient] is always a bit difficult when you only take on the role of a nurse [...]. (D_{13a})

However, four participants also mentioned that they missed the support to switch between the roles during training. They would have liked it to train the same transfer each, and afterward watch the feedback for both training conducts.

In regard to **DG3**, seven participants stated that the theoretical explanations helped them to aid their understanding of the patient transfers. Still, as the usage time of *KiTT* was limited, five participants also mentioned that they would require more time to fully read the theory related texts. Although two participants appreciated that *KiTT* supports the most relevant patient transfer scenarios, six of the participants suggested that *KiTT* should support more different scenarios in the future (D_{2a+b}, D_{3a+b}, D_{13b}, D_{5b}). This would be necessary for a permanent use of *KiTT*. Also, three participants wished for scenarios that consider patients with a different body mass (D_{11a+b}), and different symptoms (D_{13b}).

Finding 1: The subjective user experience of *KiTT* is good. The system provides an adequate support for the learning in a skills-lab context. The participants experienced the implementation of the design goals as mostly positive. However, there is potential to improve *KiTT*. The animations’ clarity should be enhanced, and the key audio instructions should be enabled by default. The augmented reality tutorial should either be improved or removed. While the support of the roles ‘nurse’ and ‘patient’ was appreciated, it seems promising to also allow for role changes during the training in the future. Finally, for a future more permanent use, further transfer scenarios should be supported. These might also include scenarios for patients with different body masses and symptoms.

RQ2 *Learning of Kinaesthetics for the ergonomic transfer of patients.* During the interview, the participants confirmed that the current support for the learning of Kinaesthetics-based patient transfers is low. One participant stated:

“And in general, I think that in regard to the whole topic [of transferring patients based on Kinaesthetics], the training is lacking. We do this [for one day]. Maybe also one time for two days. But yes, if you are not directly in [the clinic] afterward and you immediately train everything once more, then you do not have all of it [learned so that you can apply it] and forget most of it again. [laughs]” (D_{7b})

The mean scores of the ‘System Evaluation Questionnaire’ indicate that *KiTT* helped the participants to increase their knowledge about Kinaesthetics, and that they thought that *KiTT* could help them to improve the practical application of Kinaesthetics in their daily work (see Fig. 5). The mean scores of the ‘Self Evaluation Questionnaire’ point in the same direction (see Fig. 7).

The results of a t-test showed that the participants estimated the movement sequences that they performed after the use of *KiTT* ($M = 3.52$, $SD = 0.75$) statistically significantly more conform with Kinaesthetics than the movement sequences that they performed pre system use ($M = 2.12$, $SD = 0.82$), $t(24) = 7.00$, $p < 0.0001$. A second t-test indicated that the participants also estimated the movement sequences that they performed to transfer the simulated patient post system use ($M = 3.36$, $SD = 0.69$) statistically significantly more ergonomically correct than the movement sequences that they performed before the use of *KiTT* ($M = 2.48$, $SD = 0.81$), $t(24) = 4.74$, $p < 0.0001$. One participant confirmed in the interview that the transfer of the simulated patient felt easier after s/he had learned with *KiTT*:

“I found the ... the transfer [of the simulated patient] now the second time [after the use of KiTT] much easier than when I just did it the way I always do it. Because, actually, you have to do less yourself.” (D_{1b})

However, for the video ratings of the professional Kinaesthetics teacher (see Fig. 8), a t-test showed no statistically significant effect for how conform with Kinaesthetics the teacher rated the participants performance pre ($M = 1.76$, $SD = 0.71$) and post system use ($M = 1.88$, $SD = 0.82$), $t(24) = 0.51$, $p = 0.612$. A second t-test also showed no statistically significant effect for how ergonomically correct the teacher rated the movement sequences that the participants performed before ($M = 1.40$, $SD = 0.85$) and after the use of *KiTT* ($M = 1.84$, $SD = 0.83$), $t(24) = 1.70$, $p = 0.102$.

Nevertheless, we found a statistically significant effect for the 18 participants who trained in the role ‘nurse’ and successfully conducted the feedback and reflection on their own performance for at least one transfer, without being influenced by the white-rectangle issue on their iPad (see Fig. 9). For this measure, we excluded eight participants (for details, see the second and the third paragraph of section 4.5). A t-test indicated that the teacher rated the ergonomic correctness statistically significantly higher for the movement sequences that the 18 participants performed after they used *KiTT* ($M = 1.94$, $SD = 0.91$), in contrast to before ($M = 1.28$, $SD = 0.45$), $t(17) = 2.38$, $p = 0.029$. Related to this, the participants’ statements in the interview suggest that especially *KiTT*’s support for feedback and reflection could help them to assess and improve their own behavior.

“The reflective questions. And through them, one could see if what one did was really back-friendly. So one could better reassess oneself.” (D_{5b})

“So I think the feedback is especially good. So that the text is next to [the video] and that it directly states what one, what I did wrong, and how it would be better to do it and what one should pay attention to.” (D_{11a})

Although the teacher’s video ratings reveal a significant effect in regard to how ergonomically correct 18 of the participants transferred the simulated patient, the teacher’s bullet point statements about what he deemed *not* ergonomically correct show no considerable difference between the types of mistakes that the participants made before and after the use of *KiTT*. However, our analysis of the bullet point statements revealed that working with a *wrong bed elevation* is a mistake that very many participants made pre and post system use ($n_{pre} = 18$; $n_{post} = 15$). Although *KiTT* instructs

Figure 7: Mean scores of the 5-point semantic differentials in the custom ‘Self Evaluation Questionnaire’ for all participants except D_{10a}. Statistically significant differences are indicated by an asterisk.

Figure 8: Mean scores of the 5-point semantic differentials that the professional Kinaesthetics teacher answered to rate the videos for all participants except D_{10a}. We found no statistically significant differences.

Figure 9: Mean scores of the 5-point semantic differentials that the professional Kinaesthetics teacher answered to rate the videos for the 18 participants who completed the feedback and reflection for at least one patient transfer that they trained in the role ‘nurse’ without having the white-rectangle issue on their iPad. Statistically significant differences are indicated by an asterisk.

users to adjust the bed properly and provides feedback for the issue, the participants did not adjust the bed in almost as many cases after they used KiTT, as before. The high number of participants who committed the mistake suggests that future systems should provide a dominant warning for the issue, to increase the support for ergonomic work.

For the teacher’s ratings of how conform with Kinaesthetics the 18 participants performed the movement sequences, a t-test indicated no statistically significant effect between the transfers that took place before ($M = 1.72$, $SD = 0.56$) and after the use of KiTT ($M = 1.94$, $SD = 0.85$), $t(17) = 0.94$, $p = 0.361$. However, the

teacher’s bullet point statements suggest that after learning with KiTT, fewer participants used *fast and hectic movements* ($n_{pre} = 6$; $n_{post} = 2$), and that participants avoided it to make *no use of their environment* ($n_{pre} = 4$; $n_{post} = 0$). This can be related to the concept ‘human function’ of the Kinaesthetics care conception. The concept suggests that the movement of patients should happen in a manner that allows them to transfer their bodies weight to the environment, as this can help to protect nurses’ health [23]. For example, the bed can be used as a supportive surface along which a nurse can transfer a patient by moving one body mass after the next to transfer the patient step by step upwards in bed. In contrast, fast movements

and too large movement steps—like dragging the patient upwards in bed in one swift motion—should be avoided.

Finding 2: *KiTT* provides a good subjective support for the learning of Kinaesthetics. The use of *KiTT* led the participants to rate their performance for the transfer of a simulated patient significantly more conform with Kinaesthetics and more ergonomically correct than before. The teacher's ratings of the video recordings confirm a significantly higher ergonomic correctness of the participants' performance after the use of *KiTT*, for the 18 participants who trained in the role 'nurse' and successfully conducted the feedback and reflection on their own performance for at least one transfer. However, the teacher's video ratings do not show a significant pre/post system use difference for the conformity with Kinaesthetics. Still, the teacher's bullet point statements indicate that the participants made better use of their environment and avoided fast and hectic movements after they had learned with *KiTT*. A long-term use of a system like *KiTT* might show a stronger increase in knowledge about the application of Kinaesthetics. Besides this, future supportive systems should emphasize the importance to adjust the bed to a proper elevation for work.

RQ3 *Integration and extension of conventional practices.* According to the yes/no question in the 'System Evaluation Questionnaire', all participants could imagine the future use of *KiTT*. The mean scores of the 'System Evaluation Questionnaire' also show that the participants considered the integration of *KiTT* into conventional teaching methods as much desirable (see Fig. 5). When asked how they experienced *KiTT* in contrast to conventional practices to support the learning, eight participants mentioned that they see *KiTT* as superior to books (D_{5a+b}, D_{7b}, D_{8a}, D_{10a+b}, D_{11a+b}).

"[...] I would say if one reads through a book about how to do [a Kinaesthetics-based patient transfer], [KiTT] is [in comparison] of course much more clear and much easier to understand [...]" (D_{7b})

Six participants (D_{1a}, D_{6a}, D_{7a+b}, D_{9a+b}) suggested that *KiTT* should be intertwined with the Kinaesthetics basic course. This could help to make sure that *KiTT* is introduced early on during the nursing-care students' education, which was deemed especially important by six participants (D_{1b}, D_{3a}, D_{5b}, D_{12b}, D_{13a+b}). An early introduction of *KiTT* could aid the learning of Kinaesthetics before students get used to potentially non-ergonomic work patterns.

Most participants stated that they like the idea to use *KiTT* for learning in the nursing-care school. Besides the use in the school's training room, six participants suggested that *KiTT* might also be used in training rooms at clinics (D_{1a}, D_{3b}, D_{5a}, D_{12a+b}, D_{13b}). Moving from the support for learning towards the practical application, nine participants proposed the use of *KiTT* to support them directly during their daily work (D_{1a+b}, D_{2a+b}, D_{3a+b}, D_{4a+b}, D_{5b}).

"[...] And if they tell me, for example at the ward, 'mobilize the patient' [and] I still feel unsure about it, I just go to the app, can have another quick look at how it is done, and then go to the patient." (D_{4a})

Although *KiTT* was designed with a focus on the support of learning, *KiTT* could be combined with a smartphone-based component like NurseCare [12] that focuses on nurses' support during work in

the future. Also related to mobile use scenarios, some participants suggested that *KiTT* could support them to learn at home—e.g., with a relative—(D_{1b}, D_{3a}, D_{10b}, D_{13b}) or to train transfer situations with real patients in the clinic (D_{3a+b}, D_{12b}).

"[...] it would be really cool if we had a tablet like that on the ward and I even think that my, well that I [met] many patients [...] to which I could have gone and said 'hey, I have a new method here, can I train it with you?'" (D_{12b})

Finally, two participants emphasized that *KiTT* should be used "every semester" (D_{9b}) and embedded in the existing curriculum (D_{7b}). This embedding in the curriculum might be extended from the school to the clinic context. Five participants suggested that *KiTT* could be integrated into advanced training courses in the clinic (D_{3a+b}, D_{5a}, D_{9b}, D_{10a}). Furthermore, not everyone can or wants to use their free time for learning. Four participants suggested that it would be great if part of their regular school or work hours could be used for learning (D_{1a}, D_{3b}, D_{12a}, D_{13b}).

"Whereby I would also not think it a bad idea if one's employers would offer the time to [learn with KiTT] with colleagues at the ward. Because I mean that also promotes the health of the employees [...]" (D_{3b})

Finding 3: All participants considered a future integration of *KiTT* into conventional teaching methods as desirable. Based on the participants' suggestions, *KiTT* should be introduced early, potentially as part of a Kinaesthetics basic course. Also, a clear integration in the existing curriculum that would allow the learning during school or work hours seems promising. Besides this, *KiTT* could additionally support mobile learning scenarios at home or together with patients in their respective rooms, in a clinic, in the future. Finally, to provide a more holistic support of nursing-care students, *KiTT* might be combined with an additional mobile component that aids the nurses during work.

5 LIMITATIONS

During the evaluation of *KiTT* some of the participants experienced technical issues. It is necessary to resolve these technical limitations for a future permanent use of a system like *KiTT* in a nursing-care school.

The evaluation of *KiTT* was conducted together with nursing-care students in a training room context at a nursing-care-school. Although to have real end-users who use the system in their real-world school context provides a good basis to gather information with a high ecological validity, potential differences in the educational setting for other countries, and the room's augmentation by cameras to increase the internal validity, limit the ecological validity of our findings.

Further on, while the conduct of the study at the nursing-care school allowed an access to a large number of participants and simplified the scheduling of the participants in dyads, the overall time for which we could conduct our evaluation in the training room context was limited to one week and the duration per dyad to two hours. Also, our results are mostly limited to females as there is a strong gender inequality in the German nursing care education (e.g., see [20]), which is reflected in our sample (21 female, 5 male participants).

The detection of the seven risk categories for which *KiTT* provides feedback is a complex task by itself. As our research partners' work related to the matter was not completed in time for our evaluation, we simulated the detection of risky behaviors by use of the Wizard of Oz method. Ideally, a professional Kinaesthetics teacher would have provided the input for the simulation. As this was not possible due to practical reasons, we decided to use a research assistant with context knowledge instead. Although the research assistant had two years of work experience in a research project related to Kinaesthetics and was familiar with the risk categories, her input was still based on her subjective judgment.

Furthermore, our evaluation uses a pre-post study design without a control group. This imposes a limitation in contrast to a study design with a control group. The participants applied the same scenario during the pre system use transfer task, the scenario-based use, and the post system use transfer task. It is possible that differences in the pre/post measurements are not only based on the treatment (the use of *KiTT*) but also influenced by a practice effect caused by a repeated training for the same scenario (repeated training for the transfer of Mrs. Maier; see Fig. 4).

Finally, our evaluation focused on the subjective experiences of the nursing-care students. We complemented our data from the nursing-care students with ratings of the pre and post system use patient transfer tasks by a professional Kinaesthetics teacher. This data helped us to gain additional insights about the nursing-care students' performance of the transfers. Nevertheless, as the data depends on the opinion of only one person, it should be treated with care. Future work might put a stronger focus on objective measures, especially when investigating the long-term learning effects of a system like *KiTT*.

6 IMPLICATIONS

The implications of our work inform the design of systems that promote the learning of ergonomic patient transfers and future research in this direction. They also suggest how a system like *KiTT* might extend conventional practices.

In line with previous work (e.g., [13]), the results of our evaluations of *KiTT* stress the importance of providing support for the learning of Kinaesthetics-based patient transfers. To our knowledge, *KiTT* is (i) the first tablet-based system that provides instructions and feedback to promote the learning of Kinaesthetics-based patient transfers, and (ii) the first such system that was evaluated in a training room context at a nursing-care school together with nursing-care students.

Our results related to **RQ1** (*User experience*) suggest that the user-centered design process of *KiTT* resulted in a learning system that provides a good user experience, adequate for the use in a training room context at a nursing-care school. The results show how the participants perceived the implementation of the three design goals that we followed to create *KiTT*. Aside from positive aspects, our results indicate that participants could not always clearly identify where they should hold part of the patient's body and how they should move it. For a permanent use of *KiTT*, more precise animations should be produced. Additionally, the animations could be extended with visual highlights and hints to communicate touch positions on the patient's body and movement directions more

clearly in the future. Some participants also suggested that they would like to switch between the roles 'nurse' and 'patient' during training so that each of them can train the same transfer directly one after the other. Future work could allow for an option to switch between different roles during training and separate the training performances to provide a distinct feedback for each performance afterward. Furthermore, to facilitate a future, more permanent use of a system like *KiTT*, the number of supported transfer scenarios should be increased. Based on participants' statements, future scenarios might also address the ergonomic transfer of patients with different body masses and symptoms.

Related to **RQ2** (*Learning of Kinaesthetics for the ergonomic transfer of patients*), participants' ratings and statements indicate that *KiTT* provides a good subjective support for the learning of Kinaesthetics. In contrast, the ratings of the study participants' transfers of a simulated patient by a Kinaesthetics teacher showed no statistically significant effect for how conform with Kinaesthetics the participants performed the movement sequence pre and post system use. However, the results of the teacher's evaluation indicate that the participants made better use of their environment and avoided fast and hectic movements after they had learned with *KiTT*. A longer use of a system like *KiTT* might allow nurses to increase their knowledge about Kinaesthetics over time. It would be interesting to investigate the long-term use of a system like *KiTT* with real end-users 'in-the-wild.' For such an investigation, it would be necessary to extend *KiTT* with a tracking system that allows for the automatic detection of risky behaviors. This would also allow for the collection of more objective measures, like how frequently users perform different risky behaviors. Such measures could help to gain further insights about users' performance over time. Besides this, the teacher's ratings indicate a statistically significant difference for how ergonomically correct a subset of the participants ($n = 18$) performed the movement sequence pre (less correct) and post system use (more correct). Furthermore, our results suggest that, although *KiTT* instructs users textually to adjust the bed to a proper work elevation and provides feedback for the issue, participants still frequently missed to adjust the bed elevation after they had used *KiTT*. Future work should provide a dominant warning for the issue to increase ergonomic work. In *KiTT*, this could be done by including the adjustment of the bed as the first step of the instructions for each patient transfer. Similar to the other steps, the step could be reflected in *KiTT*'s timeline, and a visual animation could be used to instruct users more directly.

Our results related to **RQ3** (*Integration and extension of conventional practices*) indicate that all participants considered a future integration of a system like *KiTT* into conventional teaching methods as desirable. Based on participants' statements, a holistic approach seems promising: To avoid that nurses get used to non-ergonomic work patterns, *KiTT* might be introduced early as part of nursing-care students education. For example, in line with the Kinaesthetics basic course, *KiTT* should be integrated into the educational curriculum, and the nursing-care students should be allowed to use *KiTT* during part of their school or work hours. An integration with a system like NurseCare [12]—a smartphone-based system that supports the application of Kinaesthetics-based patient transfers—could help to ease the application of what students learn with *KiTT* in the clinic. Both systems—the smartphone-based system and

KiTT—could be further developed and strongly intertwined. For example, if the smartphone-based system detects risky behaviors during the application of a patient transfer in the clinic, this information could be forwarded to *KiTT* to provide the respective nurse with individual recommendations for learning. Finally, *KiTT* could be extended with a mobile detection of risky behaviors. This would allow for an easy deployment of the system at different locations and the use of *KiTT* to train ergonomic transfers at home (e.g., with a relative). During our evaluation, we realized that the participants seldomly used both tablets for support during training. One of the tablets could be used to facilitate the mobile detection of risky behaviors in the future. For example, this could be accomplished with ARKit's [2] body-tracking capabilities. This would also remove the need for an external RGB camera to record the nurses during training. Instead, the internal RGB camera of the tablet could be used to record the nurses. Some of the risky behaviors like—the risky bending of the back—could be detected by the use of thresholds (e.g., by use of simple risk metrics [34]). For the detection of risky behaviors for all seven risk categories—including categories that require it to track the patient and the nurse—a machine learning approach might provide better results.

Aside from this, the implementation of *KiTT* may also inform tablet-based learning systems for other scenarios. For instance, to learn partner dances, dyads could be guided by a clear structure and role assignment (follow/lead dancer), and supported by feedback for detected problems, similar to *KiTT*. Future work may investigate how dyads experience the learning with a system like *KiTT* for different scenarios. The findings illustrated in Fig. 6 show what participants saw as positive and negative aspects of *KiTT*. This overview might provide helpful input for the implementation of similar systems by future work. Also, especially if future work targets the clinical domain, our findings in regard to **RQ3** might provide helpful information about how similar systems can be integrated into and extend existing conventional practices. Nevertheless, it should be noted that *KiTT* was developed for a specific application area to solve a specific problem. One should not adopt the findings of our work to other scenarios 'blindly,' without taking users' needs in the targeted application area into account. Finally, future work may also investigate how systems like *KiTT* could be extended by other components like head-mounted augmented reality displays (e.g., [8]) or smart glasses (e.g., [9]). While tablets provide a large screen space to view instructions before and feedback after the training, a head-mounted device may allow it to improve the display of simple instructions during the training conduct by visualizing the instructions in a learner's field-of-view, independent of where the learner looks.

7 CONCLUSION

We presented *KiTT*, a tablet-based system to promote the learning of ergonomic patient transfers based on the Kinaesthetics Care Conception. *KiTT* addresses the two issues: (i) that the manual handling of patients can pose a major risk to nurses' health, and (ii) that existing support for the learning and training of patient transfers based on the Kinaesthetics care conception—a concept from nursing-care that can help to address the first problem—is low. The design of *KiTT* was supported by nursing-care teachers ($N = 4$)

and nursing-care students ($N = 18$). We evaluated our final implementation of *KiTT* with 26 nursing-care students—who did not support the design process—in a nursing-care school. Our results indicate that *KiTT* provides a good user experience adequate to the nursing-school context, a good subjective support for the learning of Kinaesthetics, and that *KiTT* can promote the ergonomically correct conduct of patient transfers. They further reveal how *KiTT* can be integrated into and extend existing practices.

ACKNOWLEDGMENTS

We thank all institutions, nursing-care students, nursing-care teachers, and members of the University of Konstanz who aided our work. A special thanks goes to Rebecca and Stefan for their support in the motion capturing, and to Simon for his help in the creation of image and video materials. Furthermore, we also thank the German Federal Ministry of Education and Research for the funding of this work (Grant no.: 16SV7591).

REFERENCES

- [1] Fraser Anderson, Tovi Grossman, Justin Matejka, and George Fitzmaurice. 2013. YouMove: Enhancing Movement Training with an Augmented Reality Mirror. In *Proceedings of the 26th Annual ACM Symposium on User Interface Software and Technology (UIST '13)*. ACM, New York, NY, USA, 311–320. <https://doi.org/10.1145/2501988.2502045>
- [2] Apple Inc. 2020. Apple ARKit. <https://developer.apple.com/augmented-reality/arkit/> (Accessed: 2020-08-26).
- [3] European Kinaesthetics Association. 2008. Was ist Kinaesthetics? [GERMAN]. https://www.kinaesthetics.net/download/eka/infoblaetter/deutsch/Infoblatt_1_Was_ist_Kinaesthetics.pdf (Accessed: 2020-09-03).
- [4] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3, 2 (2006), 77–101. <https://doi.org/10.1191/1478088706qp063oa>
- [5] Kup-Sze Choi, Xuejian He, Vico Chung-Lim Chiang, and Zhaohong Deng. 2015. A virtual reality based simulator for learning nasogastric tube placement. *Computers in Biology and Medicine* 57 (2015), 103 – 115. <https://doi.org/10.1016/j.combiomed.2014.12.006>
- [6] Philo Tan Chua, Rebecca Crivella, Bo Daly, Ning Hu, Russ Schaaf, David Ventura, Todd Camill, Jessica Hodgins, and Randy Pausch. 2003. Training for physical tasks in virtual environments: Tai Chi. In *Proceedings - IEEE Virtual Reality*. IEEE Computer Society, Los Alamitos, CA, USA, 87–94. <https://doi.org/10.1109/VR.2003.1191125>
- [7] Ina Citron. 2011. *Kinästhetik-kommunikatives Bewegungslernen: mit CD-ROM [GERMAN]* (3 ed.). Georg Thieme Verlag, Stuttgart. <https://www.thieme.de/shop/Pruefungsliteratur/Citron-Kinaesthetik---kommunikatives-Bewegungslernen-9783131518934/p/000000000130014403>
- [8] Microsoft Corporation. 2021. Microsoft Hololens 2. <https://www.microsoft.com/de-de/hololens> (Accessed: 2021-01-08).
- [9] Vuzix Corporation. 2021. Vuzix Blade. <https://www.vuzix.com/products/blade-smart-glasses> (Accessed: 2021-01-08).
- [10] Dance Reality LLC. 2019. Dance Reality. <https://www.dancerealityapp.com/> (Accessed: 2020-09-15).
- [11] Ilana Dubovi, Sharon T Levy, and Efrat Dagan. 2017. Now I know how! The learning process of medication administration among nursing students with non-immersive desktop virtual reality simulation. *Computers & Education* 113 (2017), 16–27. <https://doi.org/10.1016/j.compedu.2017.05.009>
- [12] Maximilian Dürr, Carla Gröschel, Ulrike Pfeil, and Harald Reiterer. 2020. NurseCare: Design and "In-The-Wild" Evaluation of a Mobile System to Promote the Ergonomic Transfer of Patients. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20)*. Association for Computing Machinery, New York, NY, USA, 1–13. <https://doi.org/10.1145/3313831.3376851>
- [13] Maximilian Dürr, Ulrike Pfeil, Jens Müller, Marcel Borowski, Carla Gröschel, and Harald Reiterer. 2019. Learning Patient Transfers with Technology: A Qualitative Investigation of the Design Space. In *Proceedings of Mensch Und Computer 2019 (MuC'19)*. ACM, New York, NY, USA, 79–90. <https://doi.org/10.1145/3340764.3340784>
- [14] Inga-Lill Engkvist, Mats Hagberg, Arvid Lindén, and Birgitta Walker. 1992. Over-exertion back accidents among nurses' aides in Sweden. *Safety Science* 15, 2 (1992), 97–108. [https://doi.org/10.1016/0925-7535\(92\)90010-W](https://doi.org/10.1016/0925-7535(92)90010-W)
- [15] Inga-Lill Engkvist, Ewa Wigaeus Hjelm, Mats Hagberg, Ewa Menckel, and Lena Ekenvall. 2000. Risk Indicators for Reported Over-Exertion

- Back Injuries among Female Nursing Personnel. *Epidemiology* 11, 5 (2000), 519–522. https://journals.lww.com/epidem/Fulltext/2000/09000/Risk_Indicators_for_Reported_Over_Exertion_Back.6.aspx
- [16] Scott A. Engum, Pamela Jeffries, and Lisa Fisher. 2003. Intravenous catheter training system: Computer-based education versus traditional learning methods. *American Journal of Surgery* 186, 1 (may 2003), 67–74. [https://doi.org/10.1016/S0002-9610\(03\)00109-0](https://doi.org/10.1016/S0002-9610(03)00109-0)
- [17] Exit Games. 2020. Photon PUN. <https://assetstore.unity.com/packages/tools/network/photon-pun-classic-12080> (Accessed: 2020-03-19).
- [18] Exit Games. 2020. Photon Server. <https://www.photonengine.com/server> (Accessed: 2020-03-19).
- [19] Freeletics GmbH. 2020. Freeletics Coach. <https://www.freeletics.com/> (Accessed: 2020-09-15).
- [20] Hans-Werner Freitag and Andreas Schulz. 2018. *Datenreport 2018 - Kapitel 3: Bildung [GERMAN]*. Technical Report. Statistisches Bundesamt (Destatis), Wiesbaden, WI, Germany. <https://www.destatis.de/DE/Service/Statistik-Campus/Datenreport/Downloads/datenreport-2018-kap-3.html>
- [21] Olivier Friard and Marco Gamba. 2016. BORIS: a free, versatile open-source event-logging software for video/audio coding and live observations. *Methods in Ecology and Evolution* 7, 11 (2016), 1325–1330. <https://doi.org/10.1111/2041-210X.12584>
- [22] André Fringer, Martina Huth, and Virpi Hantikainen. 2014. Nurses' experiences with the implementation of the Kinaesthetics movement competence training into elderly nursing care: a qualitative focus group study. *Scandinavian Journal of Caring Sciences* 28, 4 (jan 2014), 757–766. <https://doi.org/10.1111/scs.12108>
- [23] Frank Hatch and Lenny Maietta. 2003. *Kinästhetik: Gesundheitsentwicklung und menschliche Aktivitäten [GERMAN]* (2 ed.). Elsevier, Urban & Fischer Verlag, München.
- [24] Zhifeng Huang, Ayanori Nagata, Masako Kanai-Pak, Jukai Maeda, Yasuko Kitajima, Mitsuhiro Nakamura, Kyoko Aida, Noriaki Kuwahara, Taiki Ogata, and Jun Ota. 2014. Robot Patient for Nursing Self-training in Transferring Patient from Bed to Wheel Chair. In *Digital Human Modeling. Applications in Health, Safety, Ergonomics and Risk Management*, Vincent G Duffy (Ed.). Springer International Publishing, Cham, 361–368. https://doi.org/10.1007/978-3-319-07725-3_36
- [25] Zhifeng Huang, Ayanori Nagata, Masako Kanai-Pak, Jukai Maeda, Yasuko Kitajima, Mitsuhiro Nakamura, Kyoko Aida, Noriaki Kuwahara, Taiki Ogata, and Jun Ota. 2014. Self-Help Training System for Nursing Students to Learn Patient Transfer Skills. *IEEE Transactions on Learning Technologies* 7, 4 (2014), 319–332. <https://doi.org/10.1109/TLT.2014.2331252>
- [26] Reallusion Inc. 2020. iClone. <https://www.reallusion.com/de/iclone/> (Accessed: 2020-07-09).
- [27] Maietta-Hatch Kinaesthetics. 2020. Kinaesthetics Apps - 'Kinaesthetics Care' and 'MH Kinaesthetics' [GERMAN]. <https://www.kinaesthetics.com/at/apps.html> (Accessed: 2020-09-14).
- [28] Eric Klopfer and Josh Sheldon. 2010. Augmenting your own reality: Student authoring of science-based augmented reality games. *New Directions for Youth Development* 2010, 128 (2010), 85–94. <https://doi.org/10.1002/yyd.378>
- [29] Jan Patrick Kopetz, Daniel Wessel, and Nicole Jochems. 2019. User-Centered Development of Smart Glasses Support for Skills Training in Nursing Education. *i-com* 18, 3 (2019), 287–299. <https://doi.org/10.1515/icom-2018-0043>
- [30] Tore J. Larsson and Ulf Björnstig. 1995. Persistent Medical Problems and Permanent Impairment Five Years after Occupational Injury. *Scandinavian Journal of Social Medicine* 23, 2 (1995), 121–128. <https://doi.org/10.1177/140349489502300207>
- [31] Bettina Laugwitz, Theo Held, and Martin Schrepp. 2008. Construction and Evaluation of a User Experience Questionnaire. In *HCI and Usability for Education and Work*, Andreas Holzinger (Ed.). Springer Berlin Heidelberg, Berlin, Heidelberg, 63–76. https://doi.org/10.1007/978-3-540-89350-9_6
- [32] LimeSurvey GmbH. 2020. Limesurvey. <https://www.limesurvey.org> (Accessed: 2020-08-31).
- [33] Logitech. 2020. Logitech C920 HD Pro Webcam. <https://www.logitech.com/de-de/product/hd-pro-webcam-c920> (Accessed: 2020-08-18).
- [34] Jonathan Muckell, Yuchi Young, and Mitch Leventhal. 2017. A Wearable Motion Tracking System to Reduce Direct Care Worker Injuries: An Exploratory Study. In *Proceedings of the 2017 International Conference on Digital Health (DH '17)*. ACM, New York, NY, USA, 202–206. <https://doi.org/10.1145/3079452.3079493>
- [35] Noitom Ltd. 2020. Perception Neuron. <https://neuronmocap.com/> (Accessed: 2020-07-09).
- [36] Vern Putz-Anderson, Bruce P. Bernard, Susan E. Burt, Libby L. Cole, Fairfield-Estill Cheryl, Lawrence J. Fine, Katharyn A. Grant, Christopher Gjessing, Lynn Jenkins, Joseph J. Hurrell, Nancy Nelson, Donna Pfirman, Robert Roberts, Diana Stetson, Marie Haring-Sweeney, and Shiro Tanaka. 1997. *Musculoskeletal disorders and workplace factors: a critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back*. National Institute for Occupational Safety and Health, U. S. Department of Health and Human Services, Cincinnati, OH. <https://www.cdc.gov/niosh/docs/97-141/default.html>
- [37] Sarah Rampin, Rémi and Steeves, Vicky and DeMott. 2020. Taguette. <https://doi.org/10.5281/10.5281/zenodo.4002742>
- [38] Martin Schrepp, Andreas Hinderks, and Jörg Thomaschewski. 2017. Construction of a Benchmark for the User Experience Questionnaire (UEQ). *International Journal of Interactive Multimedia and Artificial Intelligence* 4, 4 (2017), 40–44. <https://doi.org/10.9781/ijimai.2017.445>
- [39] Martin Schrepp, Andreas Hinderks, and Jörg Thomaschewski. 2018. User Experience Questionnaire - Materials. <https://www.ueq-online.org/> (Accessed: 2020-11-06).
- [40] Simon Senecal, Niels A Nijdam, Andreas Aristidou, and Nadia Magnenat-Thalmann. 2020. Salsa dance learning evaluation and motion analysis in gamified virtual reality environment. *Multimedia Tools and Applications* 79, 33 (2020), 24621–24643. <https://doi.org/10.1007/s11042-020-09192-y>
- [41] Ben Shneiderman. 1996. The eyes have it: a task by data type taxonomy for information visualizations. In *Proceedings 1996 IEEE Symposium on Visual Languages*. IEEE Comput. Soc. Press, Boulder, CO, USA, 336–343. <https://doi.org/10.1109/VL.1996.545307>
- [42] Julia Smedley, Peter Egger, Cyrus Cooper, and David Coggon. 1995. Manual handling activities and risk of low back pain in nurses. *Occupational and Environmental Medicine* 52, 3 (1995), 160–163. <https://doi.org/10.1136/oem.52.3.160>
- [43] Tuukka M Takala, Yutaro Hirao, Hiroyuki Morikawa, and Takashi Kawai. 2020. Martial Arts Training in Virtual Reality with Full-body Tracking and Physically Simulated Opponents. In *2020 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*. IEEE, New York, NY, USA, 858. <https://doi.org/10.1109/VRW50115.2020.00282>
- [44] Alison M. Trinkoff, Jane A. Lipscomb, Jeanne Geiger-Brown, and Barbara Brady. 2002. Musculoskeletal problems of the neck, shoulder, and back and functional consequences in nurses. *American Journal of Industrial Medicine* 41, 3 (2002), 170–178. <https://doi.org/10.1002/ajim.10048>
- [45] Unity Technologies. 2020. Unity 3D Platform. <https://unity.com/> (Accessed: 2020-08-18).
- [46] Janet van der Linden, Rose Johnson, Jon Bird, Yvonne Rogers, and Erwin Schoonderwaldt. 2011. Buzzing to Play: Lessons Learned from an in the Wild Study of Real-time Vibrotactile Feedback. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11)*. ACM, New York, NY, USA, 533–542. <https://doi.org/10.1145/1978942.1979017>
- [47] Wen Wen, Xiaorui Qiao, Koshiro Yanai, Junki Nakagawa, Junko Yasuda, Atsushi Yamashita, and Hajime Asama. 2017. Skill Evaluation and Education Services for Bed-Care Nursing with Sliding Sheet with Regression Analysis. In *Serviceology for Smart Service System*, Yuriko Sawatani, James Spohrer, Stephen Kwan, and Takeshi Takenaka (Eds.). Springer Japan, Tokyo, 253–259. https://doi.org/10.1007/978-4-431-56074-6_28